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FY16 T45 Contingency Base Site Evaluations for Tactical Environment

Construction Material-Based Methodology for Military Contingency Base Construction

Case Study of Maiduguri, Nigeria

Patrick J. Guertin, George W. Calfas, Michael K. Valentino,
and Ghassan K. Al-Chaar

September 2016



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Abstract

To sustain itself as the world's premier land power, the U.S. Army needs the capability to support expeditionary forces by projecting a minimal basing footprint with reduced logistical burdens. Strategically sited Contingency Bases (CBs) allow the Army's expeditionary forces to rapidly respond and attack the enemy throughout the joint area of operations (JOA). Strategic conditions will be analyzed through the lens of eight OE variables—political, military, economic, social, information, infrastructure, physical environment, and time (PMESII-PT). The Army has neither a well-grounded methodology nor the tools to enable this type of strategic decision-making capability. Decision makers require reliable information about the situational dynamics of the operational environment to anticipate the impacts that siting and operating CBs will have on the local context, and to consider the effects of the site on the operation of CBs. The capability to anticipate CB impacts and resources draws upon the local population, which will become particularly important for engagement operations when CBs will have a longer duration of use and interaction with the local populace. This report considers access of building materials required for the construction of CBs and develops a methodology to acquire reliable information that can be replicated in other locations through the world. This work then validates the developed methodology with a case study of Maiduguri, Nigeria.

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Unit Conversion Factors

Multiply	By	To Obtain
feet	0.3048	meters
hectares	1.0 E+04	square meters
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
square feet	0.09290304	square meters
square miles	2.589998 E+06	square meters
tons (2,000 pounds, mass)	907.1847	kilograms

Abbreviations

Term	Meaning
AOD	argon oxygen decarburization
ASTM	American Society of Testing and Materials
BPLC	bagged Portland limestone cement
CB	Contingency Base
CB-SITE	Contingency Base Site Identification for the Tactical Environment
CIMENCAM	Les Cimenteries du Cameroun
CMU	cement masonry unit
FAS	firsts and seconds
FEMA	Federal Emergency Management Agency
FOB	Forward Operating Base
GIS	geographic information system
HSS	hollow structural section
HT	high tensile
IBP	International Business Publications
IUCN	International Union for the Conservation of Nature
JOA	Joint Area of Operations
JORC	Joint Ore Reserves Committee
LGA	Local government area
MDF	medium-density fiberboard
MS	mild steel
MTPA	metric tons per annum
mW	megawatt
₦	naira (monetary unit)
NCP	Nigeria Code of Practice
NIROWI	Nigerian-Romanian Wood Industry
NIRP	Nigeria Industrial Revolution Plan
NIS	Nigerian Industrial Standard
NSDA	Nigerian Steel Development Authority
OPC	ordinary Portland cement
PDF	population density factor
RCC	Reynolds Construction Company
RHA	rice husk ash
RMC	ready-mix concrete
SNC	Société Nigérienne de Cimenterie
SON	Standards Organisation of Nigeria

Term	Meaning
TPA	tons per annum
TSNL	TOP Steel Nigeria Limited
URM	unreinforced masonry
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

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Preface

This study was conducted for the Department of the Army under applied research program element T45, Project 45509, “Contingency Base Site Evaluations for Tactical Environment.” The technical monitor was Mr. Kurt Kinnevan, CEERD-CZT.

The work was performed by the Environmental Processes Branch (CNE) of the Installations Division (CN), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Mr. Harold G. (Garth) Anderson was Chief, CEERD-CNE; Ms. Michelle Hanson was Chief, CEERD-CN; and Mr. Kurt Kinnevan, CEERD-CZT, was the Technical Director for Adaptive and Resilient Installations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Dr. Ilker Adiguzel.

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1 Introduction

1.1 Background

To sustain itself as the world's premier land power, the U.S. Army needs the capability to support expeditionary forces by projecting a minimal basing footprint with reduced logistical burdens. Strategically sited Contingency Bases (CBs) allow the Army's expeditionary forces to rapidly respond and attack the enemy throughout the joint area of operations (JOA). The Army has neither a well-grounded methodology nor the tools that enable this strategic decision-making capability. Decision makers require reliable information about the situational dynamics of the operational environment to anticipate the impacts that siting and operating CBs will have on the local context and to consider the effects of the site on the operation of CBs. This capability to anticipate CB impacts on a local context becomes particularly important for engagement operations when CBs will have a longer duration of use and interaction with the local populace. Understanding of these potential impacts enables decision makers to evaluate implications of the effects of the CB life cycle for the Commander's intent in the pre-operational planning stage.

This project will develop a contingency site selection process that does not currently exist for mission planners. The more efficient siting of CBs will assist in the reduction of materiel demand, minimize footprint, reduce risk to Soldiers, and preserve freedom of maneuver and action. Contingency Base Site Identification for the Tactical Environment (CB-SITE) will enable expeditionary planning to occur prior to deployment. A geospatial decision support tool that integrates the operational environment into considerations for CB design, CB-SITE can also be used to train future planners, designers, builders, operators, and managers of CBs. When given a capability to display real-time effects that flow from parametric changes, instructors would have the means to prepare students for both expected and unexpected operational situations, once deployed. This resource would also provide CB operators and managers a tool to help analyze their camps' operational effectiveness as well as test potential operational/design outcomes based on available local resources and sociocultural impacts, prior to initiating them in practice.

Construction of military facilities is one of the most important aspects of military missions. Lessons learned from past deployments show that the construction of Forward Operating Bases (FOBs) within the boundaries of host nations can be costly in terms of money, time, and effort. As a result, this effort looks at the availability of locally sourced materials and their suitability for supporting the military mission. Future considerations of military site selection for the Army is likely to focus on unconventional warfare and assistance in areas of world that are located in populated, potentially hostile regions. As such, the region around Maiduguri, Nigeria, which is currently a hot zone for hostile activity, is used as a case study to develop and evaluate the CB-SITE methodology.

The main region of focus for this research was Maiduguri, Nigeria's capital of the Borno State. The Federal Republic of Nigeria is part of Africa's west coast. Maiduguri is located in the northeastern part of Nigeria, along the Ngadda River (Figure 1 and Figure 2). The country is bordered by Benin to the west, Chad and Cameroon to the east, Niger to the north, and the Gulf of Guinea to the south. Nigeria is the most populated country in Africa, and it is geographically larger than the U.S. state of Texas. Nigeria has a population of 177,156,000 (2014 estimate) and a total area of 356,669 square miles (923,768 square kilometers).¹ The capital city of Nigeria is Abuja, which is located in the Federal Capital Territory, and the country's monetary unit is the Nigeria naira (₦). The country's official language is English; however, hundreds of other languages are spoken throughout the country, including Yoruba, Igbo, Fula, Hausa, Edo, Ibibio, and Tiv.²

Previous work, published as ERDC-CERL TR-16-14 (Al-Chaar et al. 2016), focused on the area of Dhaka, Bangladesh, and used the same methodology.

¹ Britannica Academia, Online ed., s.v., "Maiduguri." Accessed 15 March 2016. <http://www.britannica.com/place/Maiduguri>.

² Britannica Academia, Online ed., s.v., "Nigeria." Accessed 25 March 2016. <http://www.britannica.com/place/Nigeria>.

Figure 1. Maiduguri location (Google Maps, 2016).



Figure 2. Regional view of Maiduguri (Google Maps, 2016).



The country itself has a diverse geography due to the wide range of climates throughout the country. There are also vast amounts of natural resources available throughout Nigeria, with natural gas and petroleum being the most prominent. The former capital of the country, Lagos, is the country's leading commercial and industrial city due to its location near the Gulf of Guinea. The leading commercial center of northeastern Nigeria is Maiduguri due to the railway that connects central Nigeria to the northeastern sector of the country. Maiduguri has an average temperature of

32°C and an average yearly rainfall of 650 mm. The main ethnic groups in Maiduguri include Buarbur/Bura, Kanuri, and Shuwa Arab, among others.³

1.1.1 Concrete

Concrete and its constituents—mainly cement and aggregate—are the materials of interest. Concrete comes from the Latin word “concretus,” which means “to hold together;” that is, concrete is comparable to a formable rock. Concrete is the most widely used construction material throughout the world, and it forms the backbone of many infrastructure systems. Historically, concrete is one of the oldest construction materials, and it is in use throughout the world for its accessibility, economic feasibility, and functionality. Concrete has a much lower cost per pound when compared to other building materials such as aluminum or steel.

There are two main ways to mix concrete: (1) in a batch plant off site or (2) by hand and/or a small machine mixer on site. Ready-mixed concrete is used to refer to concrete that is batched off site and transported to the job site. Ready-mixed concrete is commonly used for structural applications including but not limited to beams, columns, foundations, slabs, walls, and architectural features for curtain walls and decorative columns. Concrete provides an energy-efficient means of construction, because it provides insulation from environmental factors. Also, concrete is durable, inflammable, thermal and water resistant, and low maintenance.

The main constituents of construction concrete include aggregates, cement, water, and air. A finely ground mixture of clay or shale, gypsum, fly ash, limestone, and slag, a mixture better known as Portland cement, is the most common cement type. Aggregates used in concrete production are generally clean gravels, stones, and sands. Aggregates are characterized by their grade, which can either be fine (0.001 to 0.25 inch) or coarse (0.25 to 1.5 inch).⁴

³ Britannica Academia, Online ed., s.v., “Nigeria.” Accessed 25 March 2016. <http://www.britannica.com/place/Nigeria>

⁴ Britannica Academia, Online ed., s.v., “Concrete.” Accessed 17 January 2016. <http://www.britannica.com/technology/concrete-building-material>.

1.1.2 Wood

Wood is one of the world's oldest and most important construction resources. The properties of wood make it an excellent building material. Wood is widely available throughout the world and can be easily formed into various shapes, as desired. An estimated 3,000–4,000 species of plants produce wood that is suitable for material use. It has large economic importance, because it can be found throughout the world and is a renewable resource. Wood is also a sustainable construction material, as it is a renewable resource and, if properly managed, the world's wood resources are indefinite (USDA [U.S. Department of Agriculture] Forest Service 2010).

1.1.2.1 Natural wood

Round wood products are used to make poles, posts, and certain mine timbers and are typically given a preservative treatment. Sawn wood is referring to products derived from sawmill. The main product of sawn wood is lumber, which is used in logs, timber, or members of light-frame construction. Timber is used for heavy construction and can be classified as hardwood or softwood.

1.1.2.2 Layered wood

Veneer, which is a thin sheet of wood of uniform thickness (around 0.02–0.04 inch), is another common product and is used for plywood, furniture, and other household products. Plywood is composed of glued veneer layers, with different grains crossing each other at right angles. The material allows for stability across more dimensions than natural wood, uniform strength, splitting resistance, panel forming, and more decorative value. Structurally it is used for walls, floors, roofs, doors, and has many other applications. Similarly, laminated wood is built with glued layers of wood; however, the grain of the wood pieces are glued parallel to the member length. Laminated wood is used for load-carrying members such as beams or arches.

1.1.2.3 Wood residue and fibers

Particleboard is a product manufactured with flake-like forms of wood (typically from sawmill and other wood industries' residues) that are glued together. The product is used for interior uses such as furniture, paneling, and doors, as well as for structural purposes. Fiberboard is made from

wood fibers, which are held together by physical forces (hydrogen bonding), flowing of lignin in fibers, or interweaving of fibers. There are two types of fiberboard: insulation and compressed. Insulation board is used in construction for insulation and cushioning, whereas compressed wood has a variety of uses such as furniture, wall paneling, house siding, and concrete forms. A relatively new compressed product is medium density fiberboard (MDF), which is used for the same applications as compressed wood.

1.1.2.4 Bamboo

Bamboo is a subfamily of tall tree-like grasses with over 1,400 species located in tropical, subtropical, and mild temperate regions. It is a fast-growing plant that grows in clusters and consists of woody ringed stems called culms, which are typically hollow. Bamboo has a wide range of uses, especially in East and Southeast Asia. Some of the structural purposes of bamboo culms include planks for houses and rafts, scaffoldings, and flooring.

1.1.3 Steel

Steel is one of the most widely used construction materials, especially in the United States where it is commonly used in building practices for structures. Along with this use, steel has other practical uses in many industries. Steel is a popular material because of its relatively low cost of production, formation, and processing, the abundance of iron ore and scrap metal, and its range of mechanical properties. Steel is a metal alloy of iron and carbon, which has a carbon content from 0%–2%. The carbon content, heat treatment, and added alloy elements determine the properties of the material. There are many options for microstructure, shape, and surface finishes available for steel as a product. There are several thousand steel grades which are standardized, registered, or published globally. Steel is formed into either flat or long products, which are hot-rolled, cold-rolled, or coated on the surface. Flat products are plates, strips, and sheets while long products are made of either blooms or billets (Darity 2008).

Steel is considered to be a sustainable material. It can be recycled many times without incurring the effects of degradation in properties or performance. There is little to no waste of during steel construction. Byproducts include blast furnace slag cement and gas. The increased use of steel scrap in production creates less dependence on the raw materials, iron ore and

coal. Over 80% of steel beams are composed of scrap steel. Compared to concrete, steel has a high strength to weight ratio, which allows for smaller foundations in steel framed buildings. Steel is also a viable solution for long span structures, which offers more flexibility for change during a building's life (Darity 2008).

1.2 Objective

This effort falls under the CB-SITE program. CB-SITE's goal is to develop a geographic information system (GIS)-based decision support tool to assist U.S. Army Headquarters-level staffs in siting FOBs in theater.

This effort's objective is to address the availability of appropriate construction materials within the host nation with information that includes local material standards, quantities, and accessibility. The objective was set in order to address the considerations given below:

1. Development of country-specific construction materials database.
2. Development of a methodology that defines accessibility of construction resources based on FOB location, transportation network, population densities, and centers of material.

1.3 Methodology

Site-selection methodologies are expected to merge into a unified methodology in which all relevant factors are addressed, analyzed, and optimized to yield the best solution for decision making on where best to select a site for military missions. Availability of construction materials near the site is one of many criteria that would impact military missions. This report is a limited study on "Construction Material-Based Methodology for Military Site Selection."

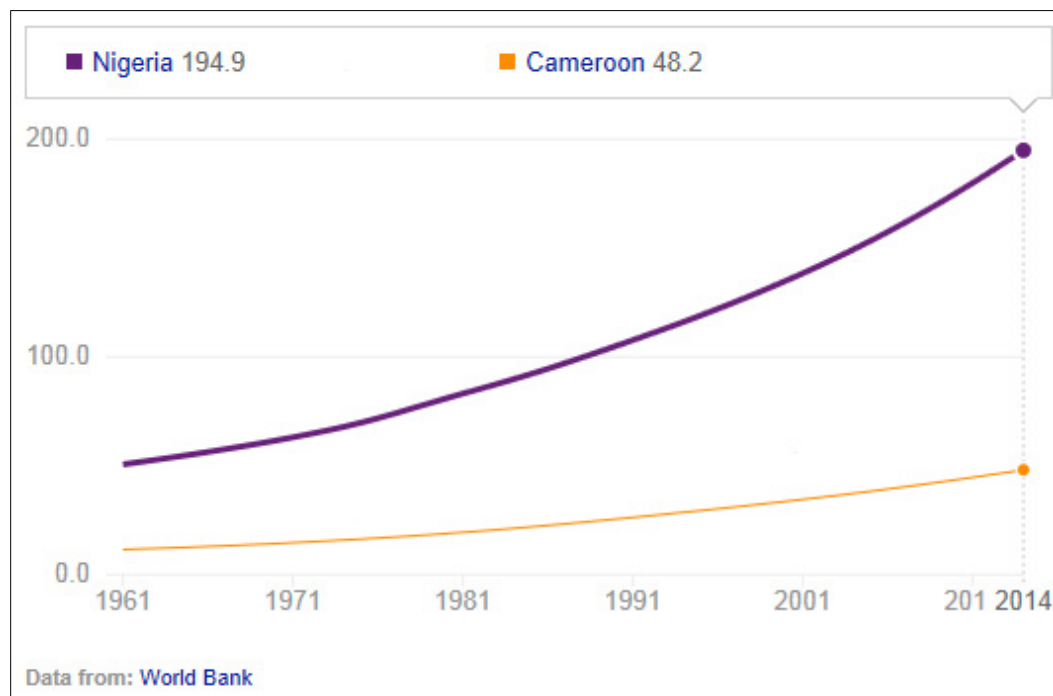
Because every location in a particular region is unique in many aspects, a single general methodology would not work well, as it would not capture all variables specific to the region under consideration. In rare cases, methodologies can be identical; however, the methodology is likely to have some variations. The approach may be the same, but the methodology should be modified to suit other, similar areas. However, it is critical in any case to identify the relevant set of variables that must be reflected in the adopted methodology. During the planning stage of any mission, a

preparation study is required to finalize a methodology suitable for the mission.

Certainly, site selection in an area such as Maiduguri is influenced by the high density of its population, among other features. Figure 3 shows the recent population density of Nigeria is about 4.04 times that of Cameroon. The population density of Nigeria is about 195 people per square mile. Therefore, any site-selection methodology should include a population density factor (PDF).

For more of the relevant factors involved in this work's methodology, please see Chapter 3.

Figure 3. Population density for Nigeria and Cameroon (World Bank Group 2016).



2 Methodology

In addition to the summary of methodology provided in Chapter 1, detailed aspects of the study's methodology follow here. As stated in Chapter 1, this work developed a methodology that defines accessibility of construction resources based on FOB location, transportation network, population densities, and centers of material.

2.1 Population density

An important component of any site-selection methodology is population density.

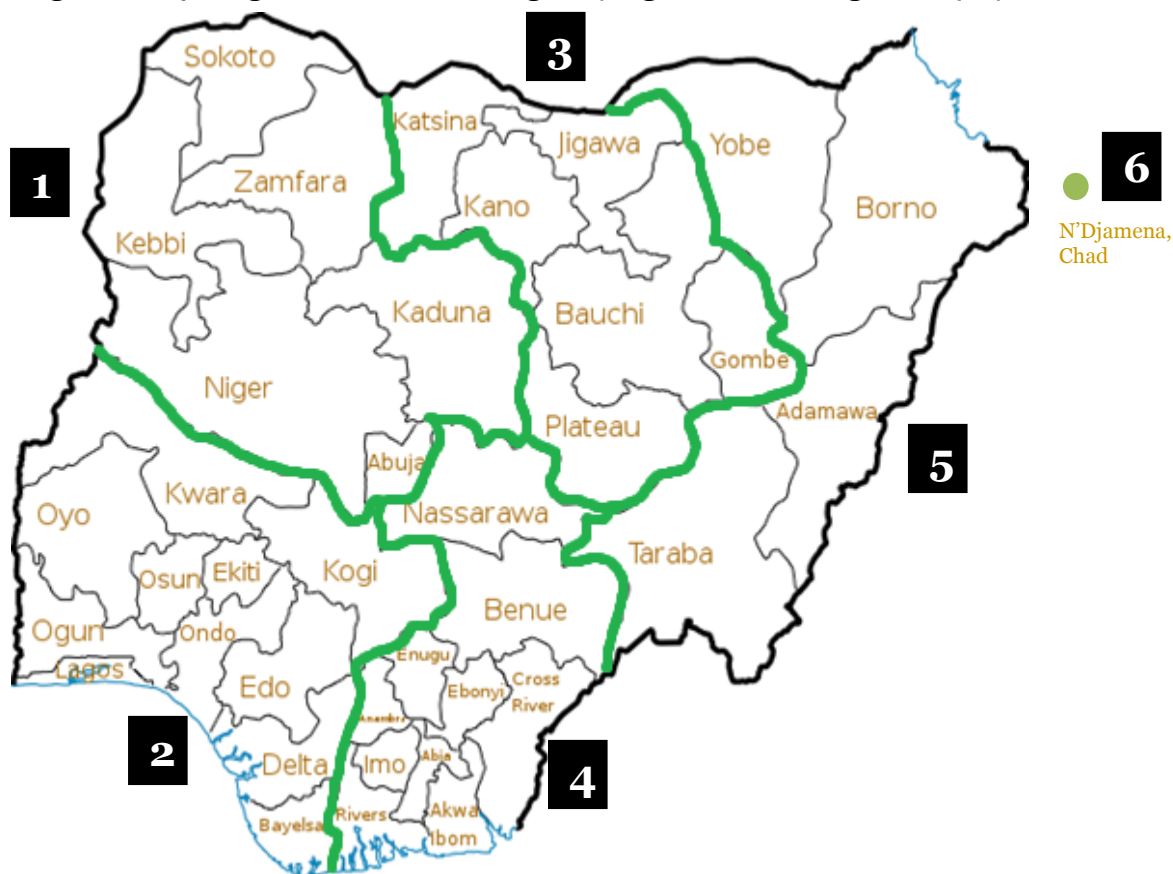
2.1.1 General regions

Table 1 provides the population and density for the five major regions in Nigeria, along with the largest neighboring city from a nearby country (N'Djamena, Chad). These six total locations are depicted in Figure 4. The populations by state can be found in Tables A1–A6 in the appendix of this report.

Table 1. Major division's populations and densities
(Nigeria Population Commission 2016).

Region	Population	Density (people/sq. km)
1: Northwest	21,712,604	93.5
2: Southwest	42,452,154	221.4
3: Northcentral	29,788,511	182.8
4: Southcentral	34,512,328	267.5
5: Eastern	11,966,193	57.6
6: N'Djamena, Chad	1,092,066	10,921.0

Figure 4. Major regions in and around Nigeria (“Nigeria States – Nigeria maps”).



The major regions were determined by the population densities of the region. The country was divided so that there were two high-density regions (Region 2: Southwest and Region 4: Southcentral), one medium-density region (Region 3: Northcentral) and two low-density regions (Region 1: Northwest and Region 5: Eastern).

For site selection in or near the vicinity of Maiduguri, the first requirement is to determine the boundaries so that the effective area can be isolated with minimum effects from adjacent areas. It is recommended here to consider the following effective areas, for simplicity and accuracy of this analysis:

- city effective region (Maiduguri),
- country effective region (Nigeria),
- cross-country effective region (Nigeria and adjacent parts of Cameroon and Chad), and
- cross-countries effective regions (Nigeria and nonadjacent countries with heavy trades).

Each region has a special level of interaction that affects the flow of construction materials to be distributed to a site under consideration. The aforementioned definitions of effective areas will help in determining a methodology for a particular region.

Using the six main regions from Figure 4, in conjunction with the descriptions provided above, it was determined that the six main regions would be considered to be included in the analysis, as they are broken down sufficiently.

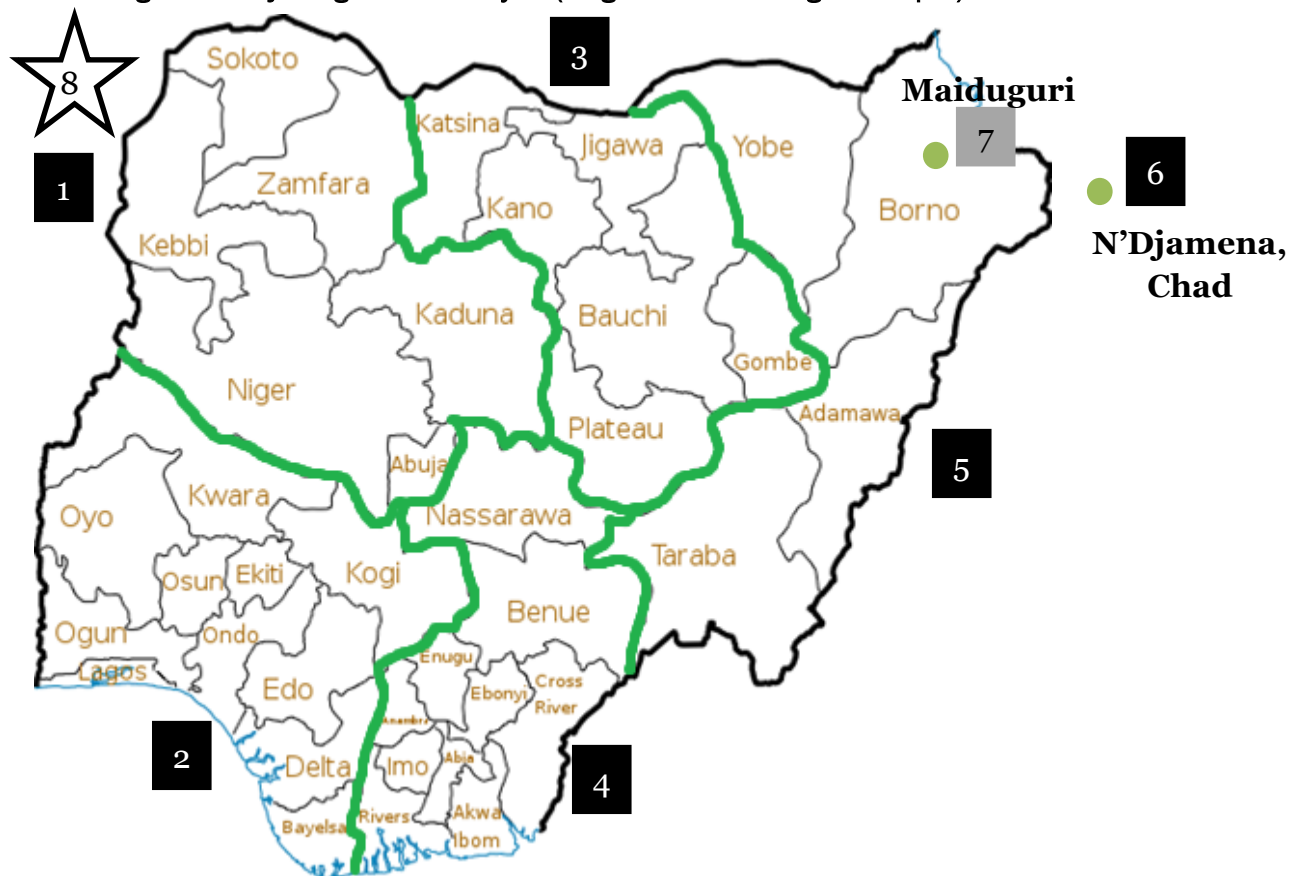
The density of the region meant that Nigeria itself was divided into five sections (Figure 4), since people control the activity of a country. For the purposes of this case study, three additional regions were considered. The first additional region is the main city under consideration—Maiduguri. The next region is an adjacent country's largest nearby city—N'Djamena, Chad. Lastly, the final region to be considered is a nonadjacent country that is a heavy trade partner with the country or city under consideration for base selection. For the purposes of this case study, it was determined there was no heavy trade partner.

Hence, the regions analyzed for this case study are classified as:

- *Region 1:* Northwest Nigeria
- *Region 2:* Southwest Nigeria
- *Region 3:* Northcentral Nigeria
- *Region 4:* Southcentral Nigeria
- *Region 5:* Eastern Nigeria
- *Region 6:* Neighboring country's largest nearby city – N'Djamena, Chad
- *Region 7:* Maiduguri, Nigeria (subset of Region 5)
- *Region 8:* Heavy trade partner with nonadjacent region – not applicable for this case study

Figure 5 provides the seven regions analyzed for the Maiduguri, Nigeria, case study.

Figure 5. Major regions for analysis (“Nigeria States – Nigeria maps”).



2.2 Building types

The Federal Emergency Management Agency (FEMA) classifies 15 different main types of buildings. These building types must be examined in order to properly evaluate a region’s construction material needs and feasibility, based on structure type. The various building types and their respective key properties are described below.

2.2.1 Building Type 1: Wood Light Frames

W1 – These buildings are single- or multiple-family dwellings of one or more stories with light building loads. The first floor may be slab-on-grade or wood raised above grade, with cripple stud walls and post-and-beam supports. Floor and roof framing consist of short, closely spaced wood joists or rafters supported on wood studs. Lateral support is provided with shear walls of plywood, stucco, gypsum board, and a variety of other materials (ASCE/SEI 31-03 2003).

W1A – These buildings are multistory, multi-unit residences that are framed with the same systems as W1, but they are often built on top of open-front garages. The first story consists of wood floor framing on wood stud walls and steel pipe columns, or concrete or concrete masonry block walls on a concrete slab (ASCE/SEI 31-03 2003).

2.2.2 Building Type 2: Wood Frames, Commercial and Industrial

W2 – These buildings are commercial or industrial buildings with a floor area of 5,000 square feet or more, and they are constructed primarily on wood framing. The floor and roof framing consists of wood joists and wood or steel trusses, glulam or steel beams, and wood posts or columns. Lateral forces are resisted by wood diaphragms and exterior stud walls sheathed with plywood, stucco, or wood sheathing (or sometimes rod bracing or a spot steel-braced frame). Large wall openings are common for storefronts or garage openings (ASCE/SEI 31-03 2003).

2.2.3 Building Type 3: Steel Moment Frame

S1 – These buildings consist of an essentially complete frame assembly of steel beams and columns. Lateral forces are resisted by moment frames that develop stiffness through rigid connections of the beam and columns created by angles, plates, and bolts, or by welding. Moment frames may be developed on all framing lines or only in selected bays. It is significant that no structural walls are required. Floors are cast-in-place concrete slab or metal deck and concrete. When the interior of the structure is finished, frames are concealed by ceilings, partition walls, and architectural column furring. Foundations consist of concrete spread footings or deep pile foundations (ASCE/SEI 31-03 2003).

S1A – These buildings are similar to S1 buildings, except for the floors and roof that act as flexible diaphragms, such as wood or untopped metal deck that are flexible relative to the frames (ASCE/SEI 31-03 2003).

2.2.4 Building Type 4: Steel-Braced Frame

S2 – These buildings consist of a frame assembly of steel columns and beams. Lateral forces are resisted by diagonal steel members placed in selected bays. Floor and roof framing consist of cast-in-place concrete slabs or metal deck on concrete. When the exterior of the structure is concealed,

walls consist of metal panel curtain walls, glazing, brick masonry, or pre-cast concrete panels. When the interior of the structure is finished, frames are concealed by ceilings, partition walls, and architectural furring. Foundations consist of concrete spread footings or deep pile foundations (ASCE/SEI 31-03 2003).

S2A – These buildings are similar to S2 buildings, except for the floors and roof that act as flexible diaphragms, such as wood or untopped metal deck (ASCE/SEI 31-03 2003).

2.2.5 Building Type 5: Steel Light Frame

S3 – These buildings are pre-engineered and partially prefabricated with transverse rigid steel frames. They are one-story in height. The roof and walls consist of lightweight metal, fiberglass, or cementitious panels. Rigid frames in the transverse direction and light rod diagonal bracing in the longitudinal direction resist lateral forces. Diaphragm forces are resisted by untopped metal deck, roof panel shear elements, or a system of tension-only rod bracing (ASCE/SEI 31-03 2003).

2.2.6 Building Type 6: Steel Frames with Concrete Shear Walls

S4 – These buildings consist of a frame assembly of steel beams and steel columns. The floors and roof consist of cast-in-place concrete slabs or metal deck with or without concrete fill. The buildings feature a significant number of concrete walls effectively acting as shear walls, either as vertical transportation cores isolated in selected bays, or as a perimeter wall system. The steel column-and-beam system may act only to carry gravity loads or may have rigid connections to act as a moment frame. The buildings will generally be mid- or low-rise (ASCE/SEI 31-03 2003).

2.2.7 Building Type 7: Steel Frames with Infill Masonry Shear Walls

S5 – This is an older type of building that consists of a frame assembly of steel beams and steel columns. The floor consists of masonry flat arches, concrete slabs or metal deck, and concrete fill. Exterior walls and possibly some interior walls are constructed of unreinforced solid clay brick, concrete block, or hollow-clay tile masonry infilling the space between columns and beams. Windows and doors may be present in the infill walls but to act effectively as shear-resisting elements, the infill masonry must be constructed against the columns and beams (ASCE/SEI 31-03 2003).

S5A – These buildings are similar to S5 buildings, except for the floors and roof that act as flexible diaphragms, such as wood or untopped metal deck (ASCE/SEI 31-03 2003).

2.2.8 Building Type 8: Concrete Moment Frames

C1 – These buildings consist of concrete framing, either a complete system of beams and columns or columns supporting slab without gravity beams. Lateral forces are resisted by moment frames that develop stiffness through rigid, monolithic beam-column connections. Moment frames may be developed on all framing lines or only in selected bays. It is significant that no structural walls are required. Floors are cast-in-place or precast concrete. Foundations consist of concrete spread footings or deep pile foundations (ASCE/SEI 31-03 2003).

2.2.9 Building Type 9: Concrete Shear Wall Buildings

C2 – These buildings have floor and roof framing that consists of cast-in-place concrete slabs, concrete beams, one-way joists, two-way waffle joists, or flat slabs. Lateral forces are resisted by cast-in-place concrete shear walls. Floors are supported on concrete columns or bearing walls. The diaphragms consist of concrete slabs and are stiff relative to the walls. Foundations consist of concrete spread footings or deep pile foundations (ASCE/SEI 31-03 2003).

C2A – These buildings are similar to C2 buildings, except for the floors and roof that act as flexible diaphragms, such as wood or untopped metal deck, and they have large aspect ratios (ASCE/SEI 31-03 2003).

2.2.10 Building Type 10: Concrete Frames with Infill Masonry Shear Walls

C3 – These buildings consist of concrete framing, either a complete system of beams and columns or columns supporting slabs without gravity beams. Exterior walls and possibly some interior walls are constructed of unreinforced solid clay brick, concrete block, or hollow-clay tile masonry infilling the space between columns and beams. Windows and doors may be present in the infill walls but to act effectively as shear-resisting elements, the infill masonry must be built against the columns and beams (ASCE/SEI 31-03 2003).

C3A – These buildings are similar to C3 buildings, except for the floors and roof that act as flexible diaphragms, such as wood or untopped metal deck, and they have large aspect ratios (ASCE/SEI 31-03 2003).

2.2.11 Building Type 11: Precast/Tilt-Up Concrete Shear Wall Buildings

PC1 – These buildings are one or more stories in height. They are constructed with perimeter concrete walls precast on the site and tilted up from the exterior of the buildings, to support all or a portion of the perimeter roof load, and they provide seismic shear resistance. Floor and roof framing consists of wood joists, glulam beams, steel beams, or open web joists. Framing is supported on interior steel columns and perimeter concrete bearing walls. Foundations consist of concrete spread footings or deep pile foundations (ASCE/SEI 31-03 2003).

PC1A – These buildings are similar to PC1 buildings, except that diaphragms consist of precast elements, cast-in-place concrete, or metal deck with concrete fill, and they are stiff relative to the walls (ASCE/SEI 31-03 2003).

2.2.12 Building Type 12: Precast Concrete Frames

PC2 – These buildings consist of concrete columns, girders, beams, and/or slabs that are precast off the site and erected to form a complete gravity-load system. Lateral forces are resisted by precast or cast-in-place concrete shear walls. Floor and roof framing consist of precast concrete planks, tees, or double-tees that are supported on precast concrete girders and columns. Diaphragms consist of precast elements interconnected with welded inserts, cast-in-place closure strips, or reinforced concrete topping slabs (ASCE/SEI 31-03 2003).

PC2A – These buildings are similar to PC2 buildings, but obtain lateral support from specially connected precast girders and columns that form moment frames. These connections are either welded inserts or cast-in-place concrete closures. Diaphragms consist of precast elements interconnected with welded inserts, cast-in-place closure strips, or reinforced concrete topping slabs. This type of construction is not permitted in regions of high seismicity for new construction (ASCE/SEI 31-03 2003).

2.2.13 Building Type 13: Reinforced Masonry Bearing Wall Buildings with Flexible Diaphragms

RM1 – These buildings have bearing walls that consist of reinforced brick or concrete-block masonry. Wood floor and roof framing consists of wood joists, glulam beams, and wood posts or small steel columns, whereas steel floor and roof framing consists of steel beams or open web joists, steel girders, and steel columns. Lateral forces are resisted by the reinforced brick or concrete block masonry shear walls. Diaphragms consist of straight or diagonal wood sheathing, plywood, or untopped metal deck, and they are flexible relative to the walls. Foundations consist of brick or concrete spread footings (ASCE/SEI 31-03 2003).

2.2.14 Building Type 14: Reinforced Masonry Bearing Wall Buildings with Stiff Diaphragms

RM2 – These buildings are similar to RM1 buildings, except the diaphragms consist of metal deck with concrete fill, precast concrete planks, tees, or double-tees, with or without a cast-in-place concrete topping slab, and they are stiff relative to the walls. The floor and roof framing is supported on interior steel or concrete frames, or interior reinforced-masonry walls (ASCE/SEI 31-03 2003).

2.2.15 Building Type 15: Unreinforced Masonry Bearing Wall Buildings

URM – These buildings consist of unreinforced masonry (URM) bearing walls, usually at the perimeter and usually brick masonry. The floors are wood joists and wood sheathing supported on the walls and on interior post-and-beam construction or wood-stud bearing walls. Interior bearing walls, when present, also consist of unreinforced clay brick masonry. The diaphragms are flexible relative to the walls, and when they exist, ties between the walls and diaphragms consist of bent steel plates or government anchors embedded in the mortar joints and attached to framing. Foundations consist of brick or concrete spread footings (ASCE/SEI 31-03 2003).

URM-A – These buildings are similar to URM buildings, but features all floors and/or roof constructed of materials that form a rigid diaphragm, usually concrete slabs or steel joists with flat-arched unreinforced masonry. In regions of low seismicity, more recent construction consists of metal deck and concrete fill supported on steel framing (ASCE/SEI 31-03 2003).

Overall, the 15 different buildings types have different construction methods and materials, both of which must be taken into account when determined the most suitable building type for a particular region (ASCE/SEI 31-03 2003).

As stated previously, the importance of these building types must be examined in order to properly evaluate a region's construction material needs and feasibility, based on structure type. Table 2 provides a ranking of building types' importance in terms of most and least suitable for the region. It was determined that due to availability of construction resources as well as conditions within the country, unreinforced masonry walls (Building Type 15), reinforced masonry walls – flexible (Building Type 13), and wood light frames (Building Type 1) are the most suitable FEMA building types for the Maiduguri region.

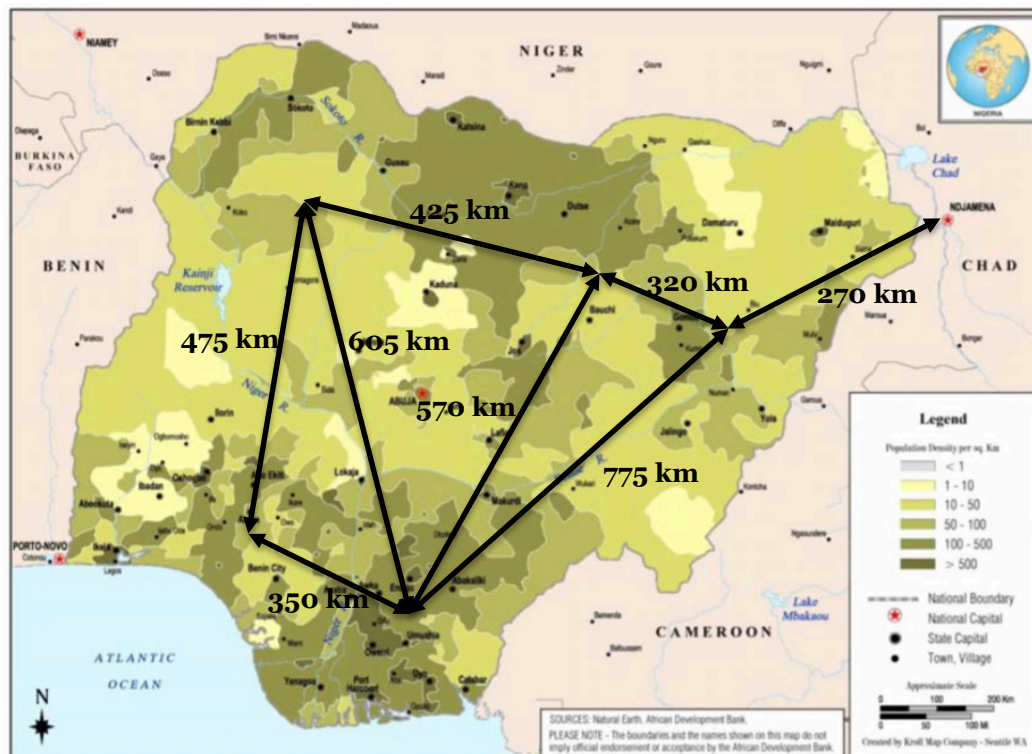
Table 2. Ranking of FEMA buildings from most to least suitable (ERDC-CERL, 2016).

Ranking	FEMA building type, ranked from most to least suitable
1.	15. Unreinforced Masonry Walls
2.	13. Reinforced Masonry Walls – Flexible
3.	1. Wood Light Frame
4.	2. Wood Frames, Commercial and Industrial
5.	3. Steel Moment Frames
6.	14. Reinforced Masonry Walls – Stiff
7.	8. Concrete Moment Frames
8.	7. Steel Frames with Infill Masonry Walls
9.	11. Precast/Tilt-up Concrete Shear Wall Buildings
10.	5. Steel Light Frames
11.	12. Precast Concrete Frames
12.	10. Concrete Frames with Infill Masonry Walls
13.	9. Concrete Shear Walls
14.	6. Steel Frames with Concrete Shear Walls
15.	4. Steel-Braced Frames

2.3 Effective proximity factor

The next parameter to be considered is the effective proximity factor. This rough estimate of the influence that neighboring regions have on each other was found by using the density of each region and the distance between each region, as the combination of two neighboring regions' population density and region proximity play an important role for each respective region. Figure 6 provides the population density map for Nigeria, and the distances between the centers of each of the six regions.

Figure 6. Population density and distance between major regions (African Development Bank 2013).



Using the distances between major regions from Figure 4 and Figure 5, along with the known density for any given region, the effective region proximity factor was determined. This factor is a rough estimate of the influence that neighboring regions have on each other, and it is found by using the density of each region and the distance between them. It was determined that the larger the effective proximity factor was between two regions, the greater influence they have on each other.

Table 3 provides the effective proximity factors between all regions in this case study. Figure 7 provides a visual representation of the adjacent region's effective proximity factors. The density of each region is listed at the endpoint of each arrow, whereas the effective proximity factor between two regions is located at the midpoint of each respective line. Together, Figure 6 and Figure 7 show that the closer two regions are to each other, the greater is the effective proximity factor.

Figure 7. Density and effective proximity factor (African Development Bank 2013).

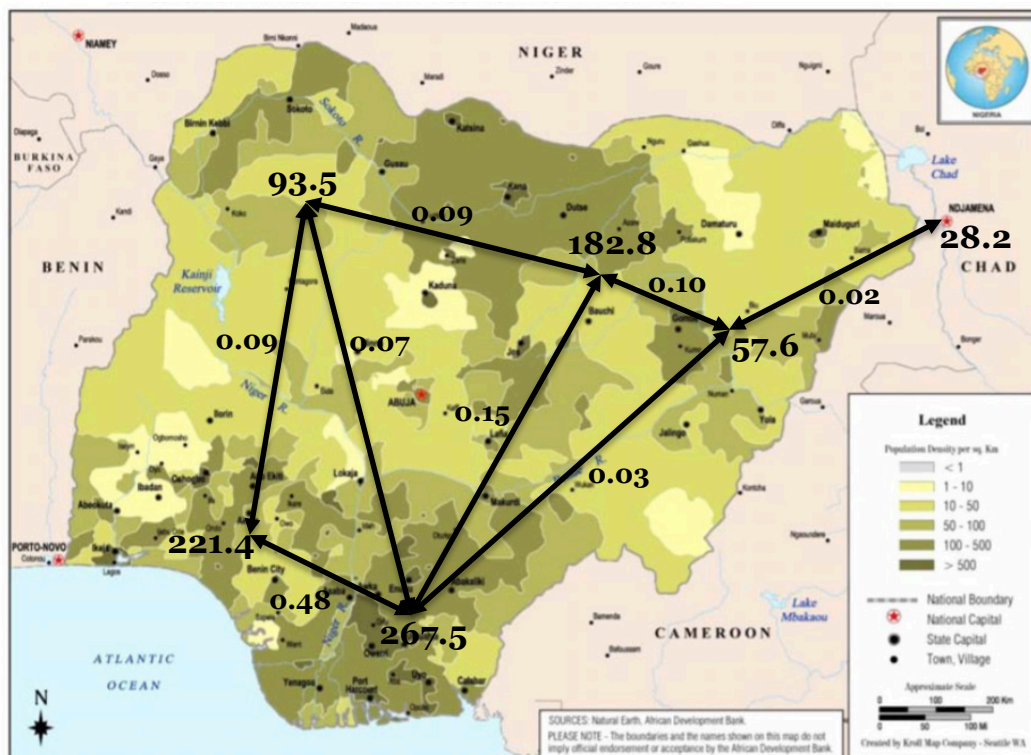


Table 3. Effective proximity factor between major regions (Nigeria Population Commission 2016).

First Region No. and Name	Second Region No. and Name	Density of First Region (people/sq. km)	Density of Second Region (people/sq. km)	Estimated Distance between Regions (km)	Effective Proximity Factor
1. Ondo	2. Oshiri	221.4	267.5	350	0.483
1. Ondo	3. Tsauni	221.4	93.5	475	0.092
1. Ondo	4. Miya	221.4	182.8	690	0.085
1. Ondo	5. Damboa	221.4	57.6	980	0.013
1. Ondo	6. N'Djamena	221.4	28.2	1255	0.004
2. Oshiri	3. Tsauni	267.5	93.5	605	0.068
2. Oshiri	4. Miya	267.5	182.8	570	0.151
2. Oshiri	5. Damboa	267.5	57.6	775	0.026

First Region No. and Name	Second Region No. and Name	Density of First Region (people/sq. km)	Density of Second Region (people/sq. km)	Estimated Distance between Regions (km)	Effective Proximity Factor
2. Oshiri	6. N'Djamena	267.5	28.2	1035	0.007
3. Tsauni	4. Miya	93.5	182.8	425	0.095
3. Tsauni	5. Damboa	93.5	57.6	745	0.010
3. Tsauni	6. N'Djamena	93.5	28.2	1000	0.003
4. Miya	5. Damboa	182.8	57.6	320	0.103
4. Miya	6. N'Djamena	182.8	28.2	585	0.015
5. Damboa	6. N'Djamena	57.6	28.2	270	0.022

2.4 Infrastructure

The next parameters examined were the travel infrastructure and other necessary infrastructure parameters within Nigeria. Each figure in this section provides a reference distance between a location on the map and the main city under consideration (Maiduguri is denoted by a yellow star). Figure 8 provides the locations and distances between the major ports in Nigeria. Figure 9 and Figure 10 provide the locations and distances between the centers of the railroad network and the roadway networks in each of the five main regions of Nigeria, respectively. Next, Figure 11 provides the locations and distances between the major airport facilities within Nigeria. Lastly, Figure 12 provides the locations and distances between the centers of high flood-risk areas in Nigeria.

Figure 8. Port map for Nigeria (African Development Bank 2013).

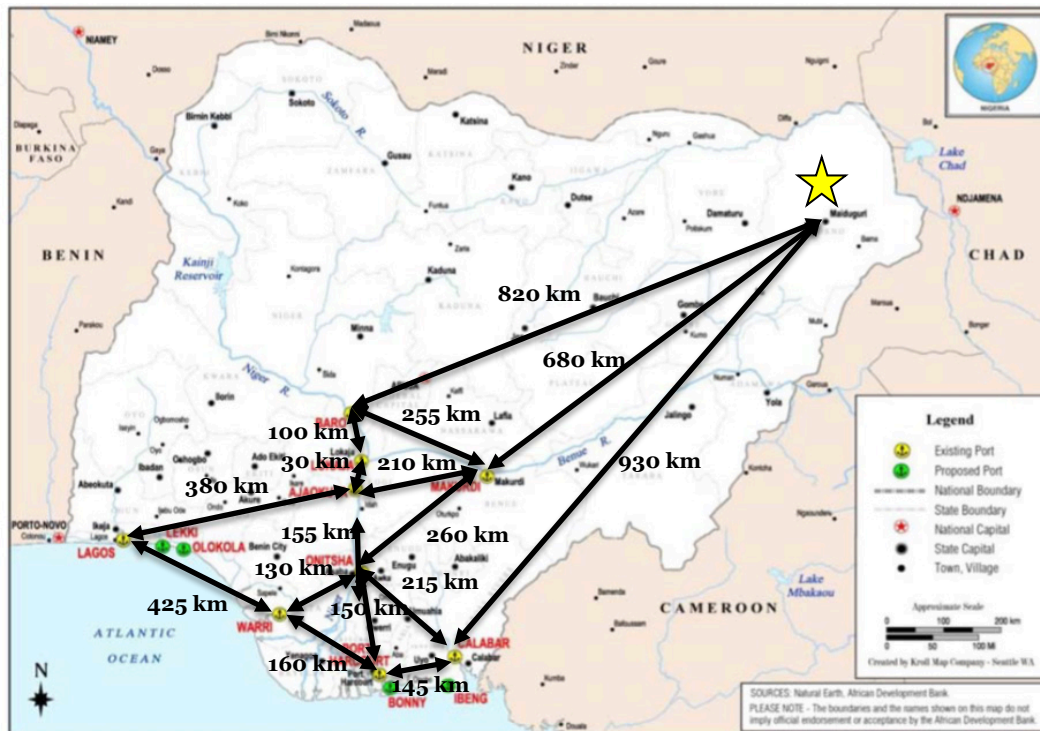


Figure 9. Railroad network in Nigeria (African Development Bank 2013).

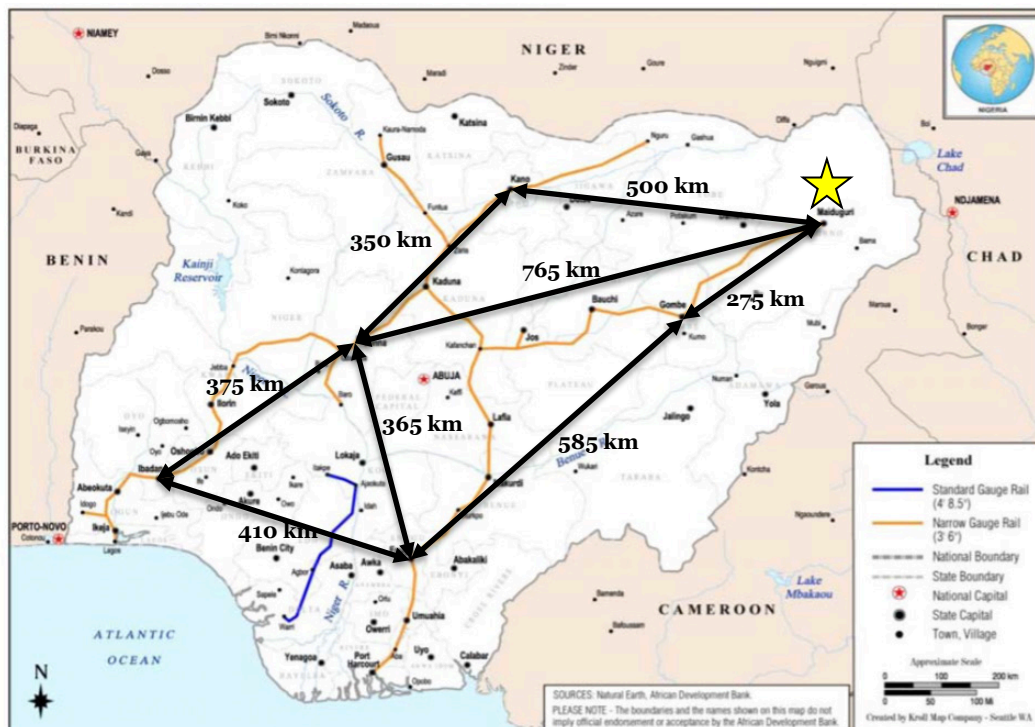


Figure 10. Road network in Nigeria (African Development Bank 2013).

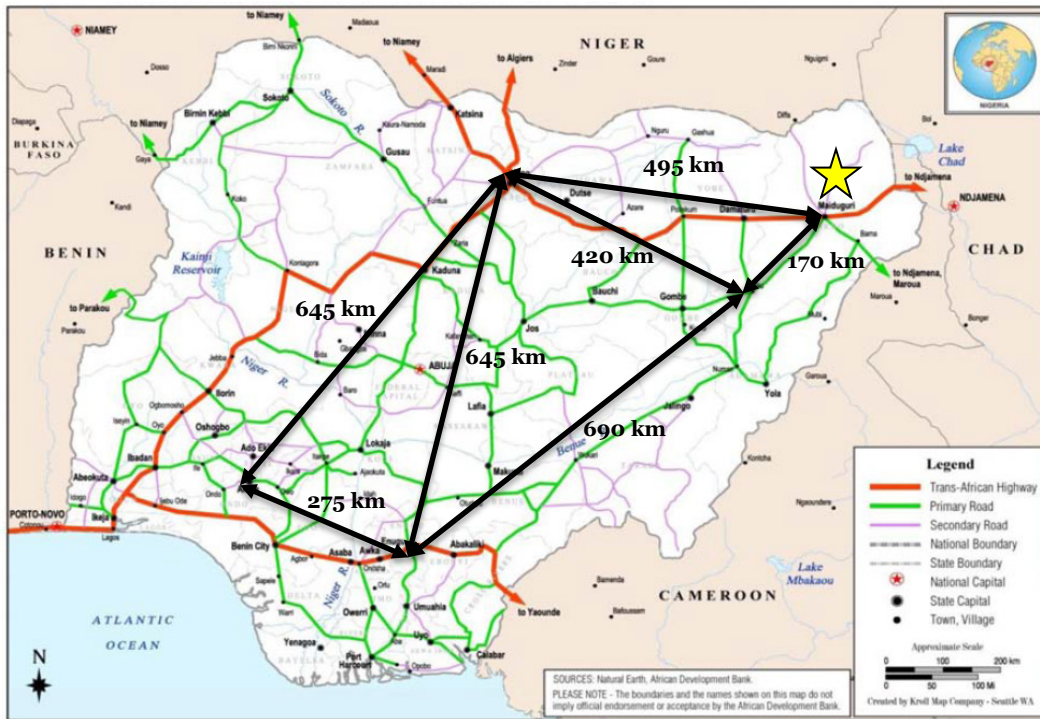


Figure 11. Airport facilities in Nigeria (African Development Bank 2013).

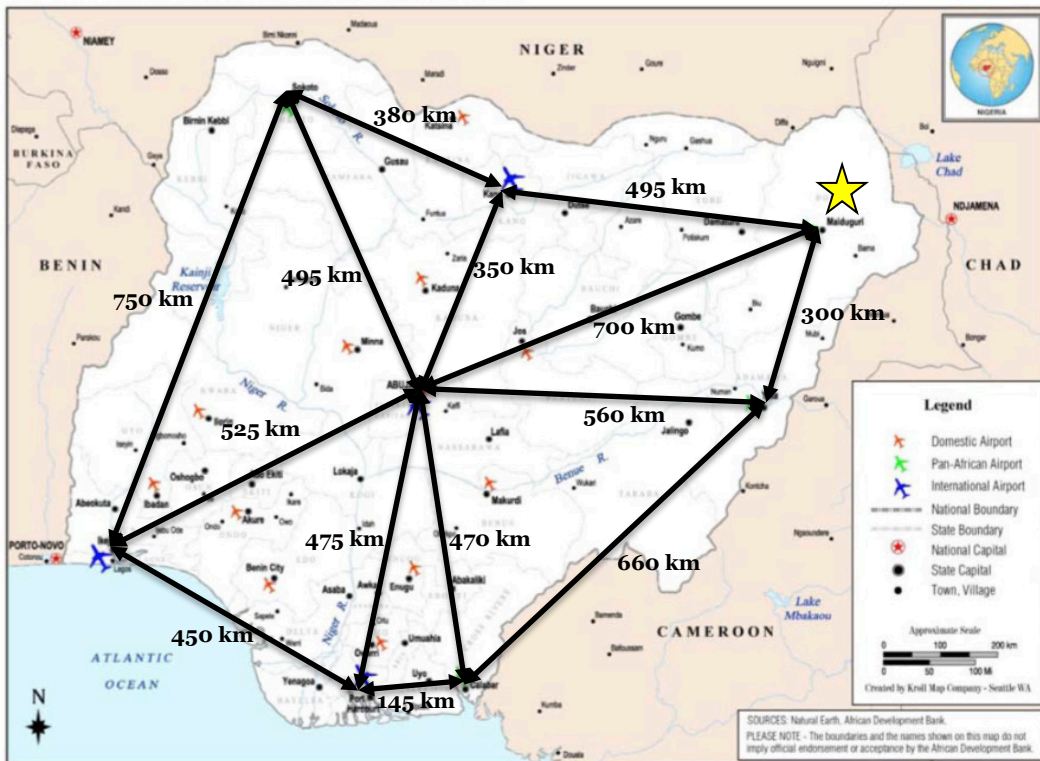
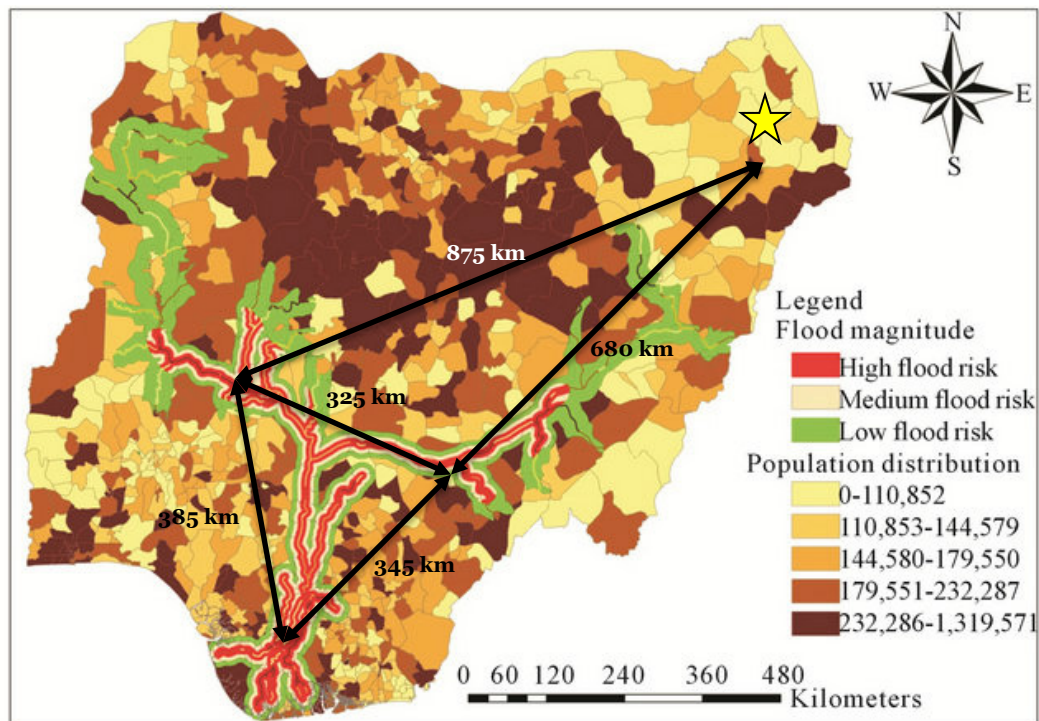


Figure 12. Flood-risk map for Nigeria (Nkeki et al. 2013).



2.5 Centers of construction resources

Upon determination of locations for various construction resources, the spatial data was used to infer the geographical centers for the various construction resources in each of the five regions. Figure 13–Figure 18 provide the geographical centers for the various construction resources in each of the five main regions from Figure 5. The construction resources are gravel, cement, ready-mix concrete, lumber, steel, and brick. In some cases, there are multiple central areas in a given region if a particular industry is very large in that region. For other construction resources, there may not be a geographical center for a particular resource in that area if the resource is not heavily or widely produced there.

Figure 13. Geographical centers, gravel resource (“Nigeria States–Nigeria maps”).

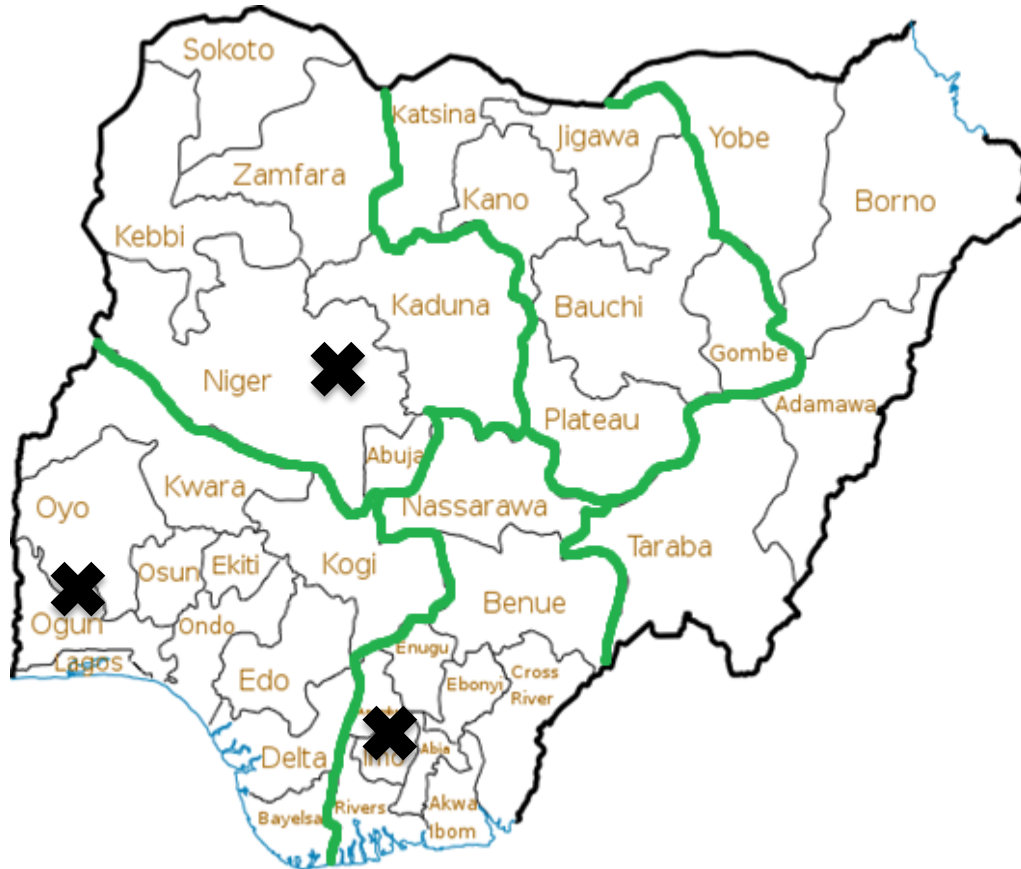


Figure 14. Geographical centers, cement resource (“Nigeria States–Nigeria maps”).

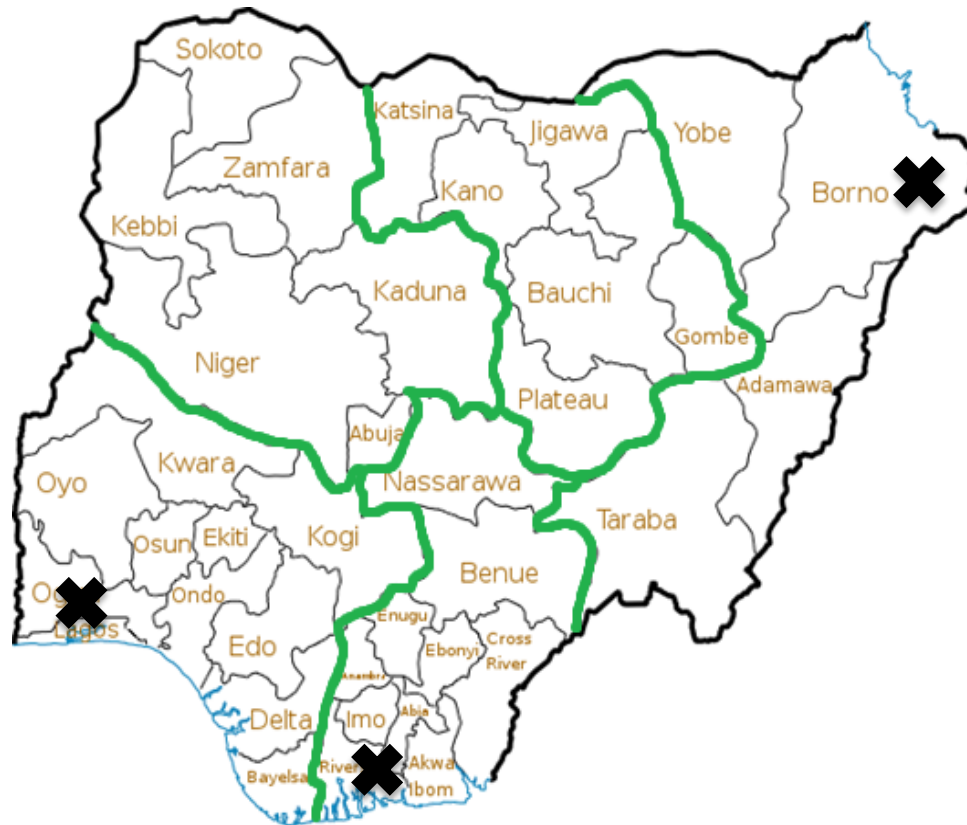


Figure 15. Geographical centers, concrete resource (“Nigeria States–Nigeria maps”).

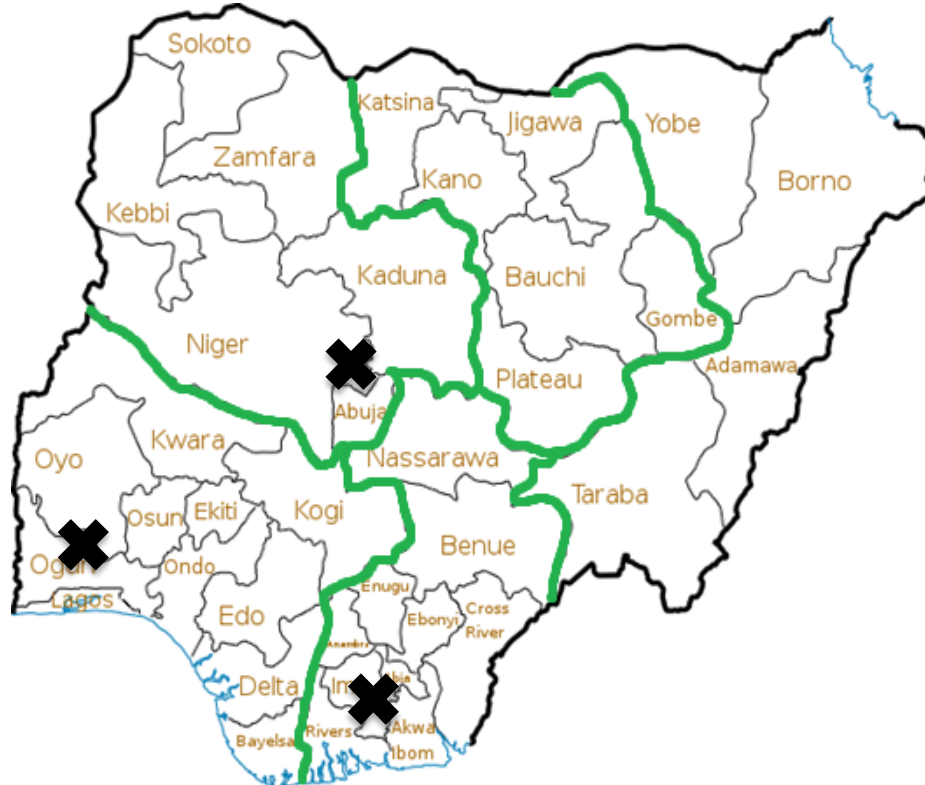


Figure 16. Geographical centers, lumber resource (“Nigeria States – Nigeria maps”).

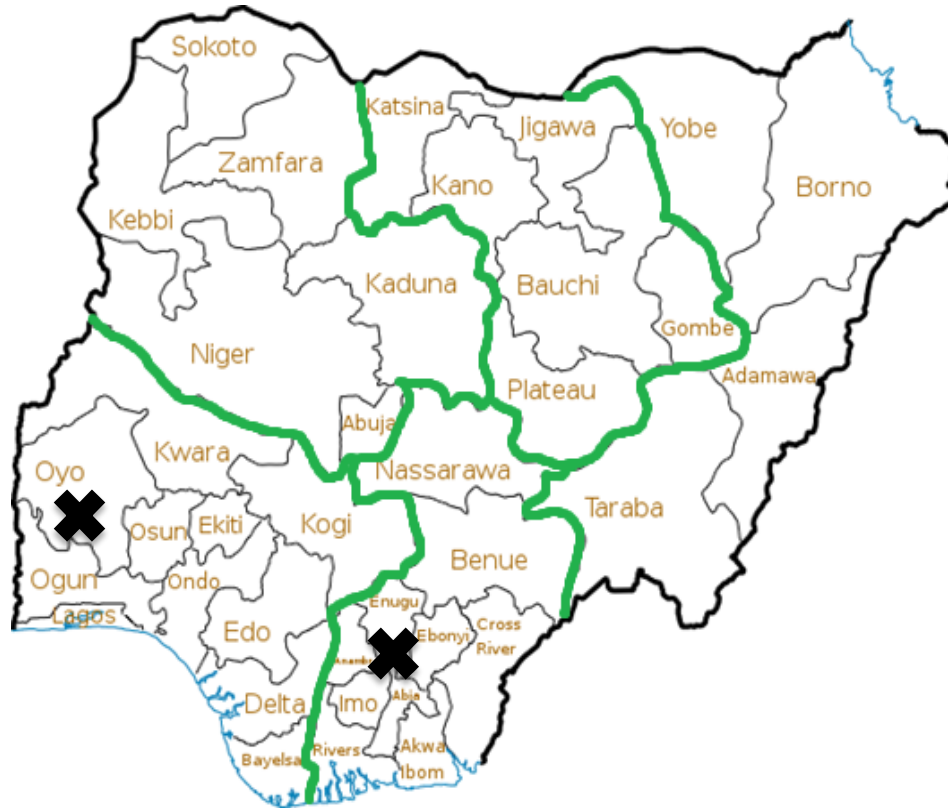


Figure 17. Geographical centers, steel resource (“Nigeria States – Nigeria maps”).

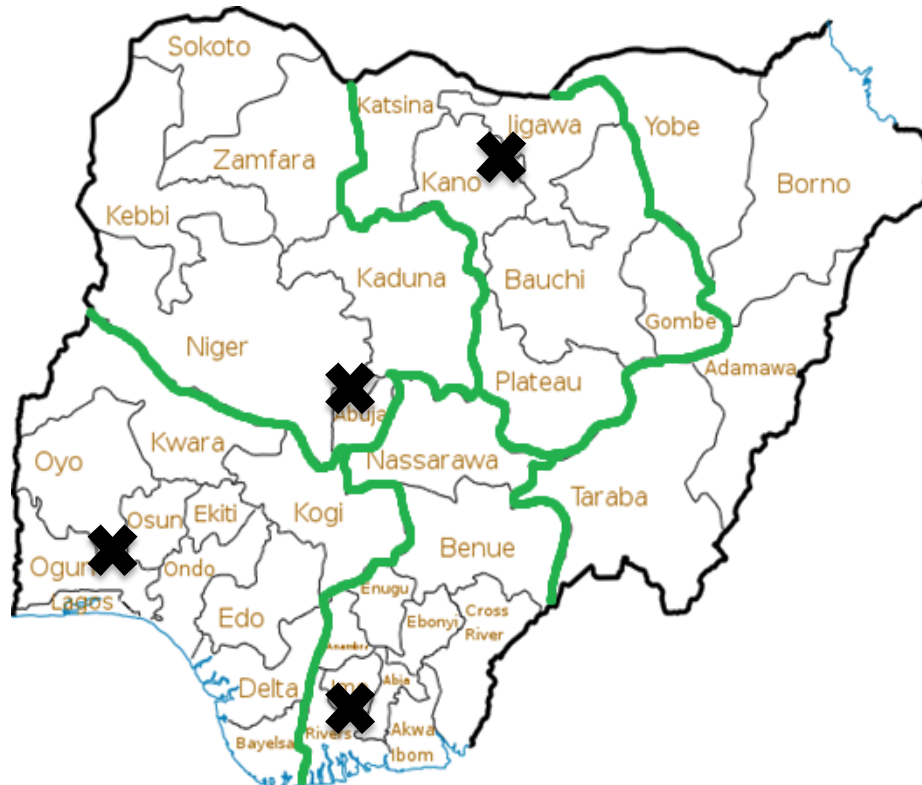
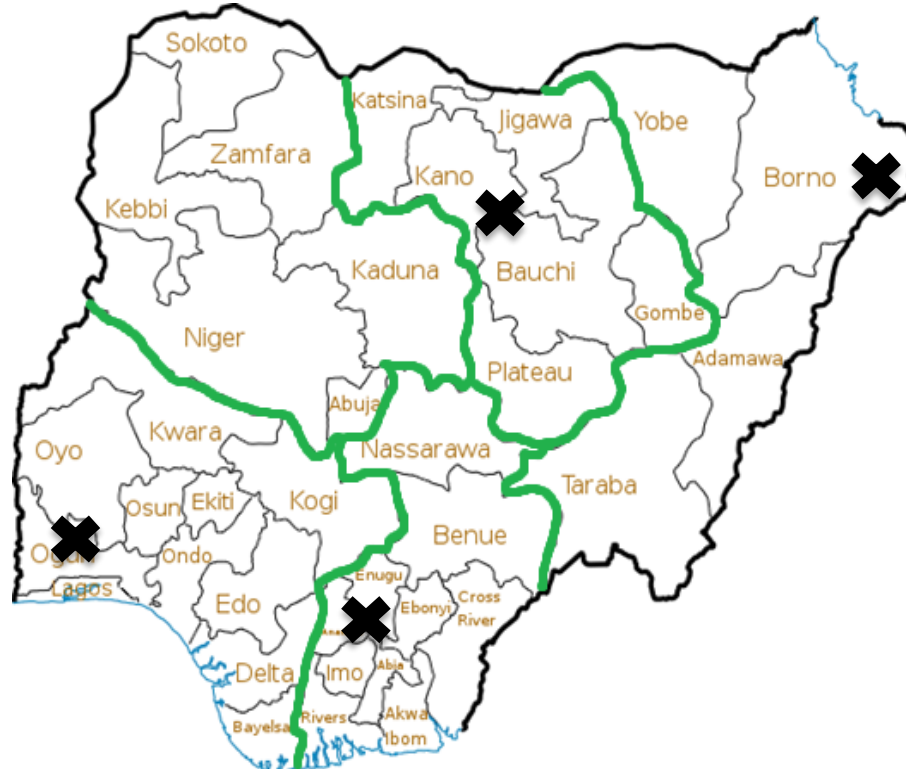


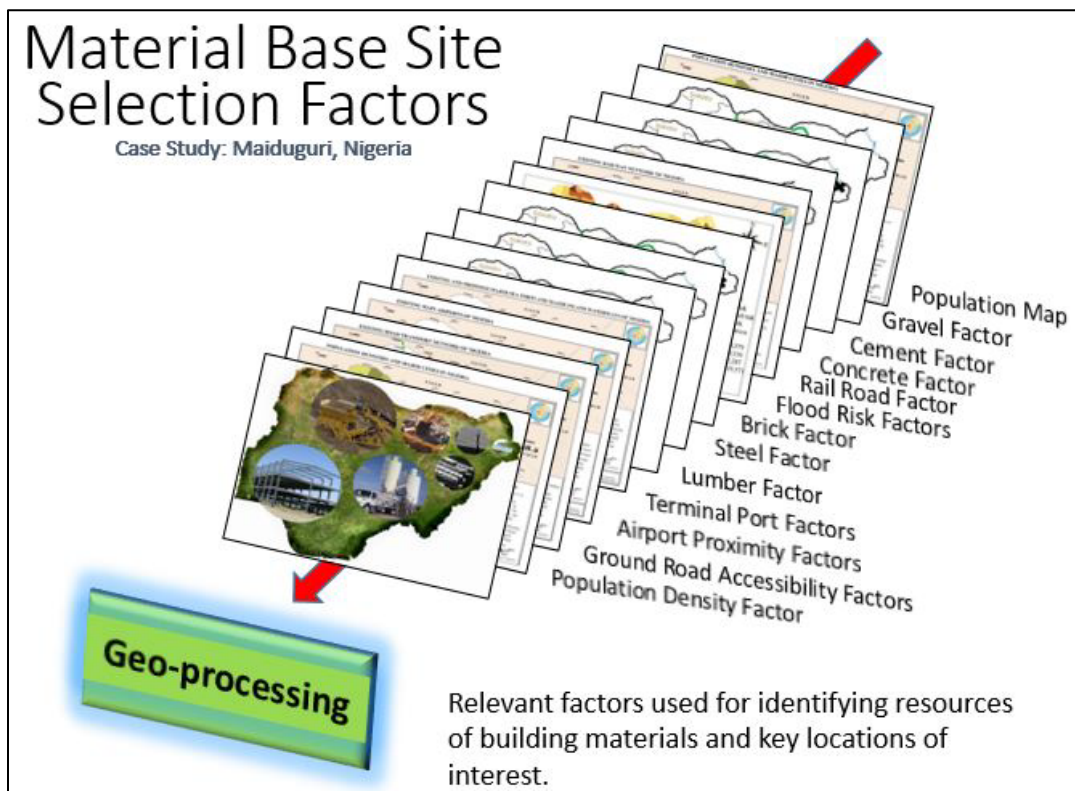
Figure 18. Geographical centers , brick resource (“Nigeria States–Nigeria maps”).



2.5.1 Construction resource for each region

Using the above information, the most widely available and used construction resource for each of the five regions was determined. Figure 19 provides a visual representation of the overlay of each of the important figures, used in part to determine the most suitable construction resources for each region.

Figure 19. Overlay of site selection construction material factors (ERDC-CERL, 2016).



The possible construction resources included: concrete, lumber, steel, and brick. The ranking of feasibility for each resource in each region is listed in Table 4. It should be noted that the various construction resource industries may be seasonal in nature due to climatic conditions. Therefore, Table 4 represents optimal conditions, with no limitations to any of the construction resource industries.

Table 4. Suitability of construction resources for the major Nigeria regions (ERDC-CERL, 2016).

Region	Most Suitable Construction Resource	Second Most Suitable Construction Resource	Third Most Suitable Construction Resource	Least Suitable Construction Resource
Southern Nigeria (Region 2 and 4)	Brick	Concrete	Lumber	Steel
Central and Northwestern Nigeria (Region 1 and 3)	Brick	Concrete	Steel	Lumber
Northeastern Nigeria (Region 5 - Maiduguri)	Brick	Steel	Lumber	Concrete

Due to the wide availability of brick/block throughout the region, this construction material was determined to be the most suitable construction resource for all three main regions.

2.6 Approach

2.6.1 Regions

The region of interest for construction materials is one of the most important factors when determining what materials are plausible for construction purposes. Methods of transportation were used to determine the boundaries to set the regions at for each construction material and the respective constituents. For example, since ready-mix concrete (RMC) is concrete that is manufactured and batched in a plant off-site of the actual construction process, a short distance range was used as the boundary. As a result, the analysis of the RMC market was conducted for Nigeria alone.

Conversely, the boundaries for determining cement and aggregate locations were much larger due to the ease of transport of each material. The study boundaries for cement and aggregate were limited to Nigeria and its surrounding countries: Benin, Cameroon, Chad, and Niger.

Wood is a widely available material; thus, the region for wood was limited to locations within the country of Nigeria.

2.6.2 Company sites

Construction materials are part of an interconnected network of resources. Each of the constituents of each construction material must be transported from one location to the next during the production process. As a result, various locations were determined to be important when gathering information on the construction materials. The following types of locations were incorporated in the data collection:

- *Corporate offices*: considered as a company's most critical location and helps regulate the company's operations
- *Factories, plants, and other manufacturing sites*: where raw materials are transformed into the final product.
- *Terminals and shipping ports*: where the product is stored for future distribution.

- *Mines, quarries, and raw material deposits*: where raw materials are extracted or available for extraction.
- *Mills*: where wood is processed (e.g., sawmill) or location used for steel manufacturing.

2.6.3 Materials database assumptions

The materials database is a collection of the various construction resources' availability by location, quantity, type of material, etc. The database includes materials such as concrete, timber, and steel, among others. Table A7–Table A12 in the Appendix of this report provide each respective materials portion of the materials database, with pertinent information for that material included.

For natural resources, research was conducted on both currently exploited resources as well as reserves of resources. In the case of reserves, the feasibility for excavation was disregarded. If the reserves were present in a particular area, they were included in the collected information. There were also assumptions made based on the available information for raw material deposits. Whether or not these material deposit locations are suitable for construction purposes was absent from a number of sources, which may lead to extraneous data in the collected information.

For production plants, data was collected to represent the current status of operation. Data was only collected for currently operating plants, and only installed capacity information was collected. If a company has new plants or capacity gains expected over the coming years, this information was disregarded when creating the materials database.

2.6.4 Construction materials

The data collection and research of materials used in production for concrete and cement were limited to those directly involved in production process. Secondary materials used to produce raw materials were disregarded.

For the case of natural resources (aggregate for use as a construction material), research was conducted on resources that are currently being exploited, along with reserves of these materials. If the reserves were present in a particular area, they were included in the collected information.

The research for wood was limited to companies who sell wood products directly. That is, locations of where companies obtain various wood products was not determined.

There were also assumptions made based on available information of raw materials. Whether or not these materials are suitable for construction purposes was absent from a number of sources, which may lead to extraneous collected information.

2.6.5 Spatial data

Three different types of spatial data were collected for each of the construction materials of interest.

The first type of data are specific and exact site locations. This latitude-longitude coordinate pair will spatially represent what it describes with precision. However, because the preciseness of material sites may vary based on available information, some information may be limited to a much broader area such as a city or a region, which is what the second type of data aims to represent.

The second type of data are approximate locations of individual sites based on limited information. If information on individual sites was not provided, but data representing a larger area was given, then the third type of data was used. It is also important to note that point data were used to capture lines and shapes in addition to specific locations, which is a greater concern for geographical areas of interest such as mountains or rivers. In those cases, a single pinpoint may not accurately represent the data. In some cases, multiple approximate pinpoints were used when expressing the location.

The third type of data are a cluster of sites that represent the characteristics of what is contained within the region.⁵ Cluster sites are also created based on researched information for each material, in order to quantify the behavior of the industry within centers of activity.

The extent of research on spatial data for Nigeria and its surrounding countries was limited to the extent of available information. For instance,

⁵ If a cluster point is superimposed over a region with site or approximate data points, then the points are to be considered exclusive from one another.

because of differences in the political system for each of the countries studied, the availability of government information on products and raw materials may vary.

Within the materials database, these data types are categorized as follows:

- S: latitude-longitude coordinate pair that represents the exact site location
- A: approximate location of an individual site provided as a latitude-longitude coordinate pair, which may be represented by a region or city if limited information is available
- C: cluster of sites to represent the characteristics of a region or city, represented as a latitude-longitude coordinate pair

Spatial data has been represented using decimal degrees with the WGS84 Web Mercator projection.

2.6.6 Data sources

2.6.6.1 Suppliers

Cement suppliers were established by using a cement industry sector search through Google.⁶ For Nigeria, information about the prominent companies and locations of their plants were determined from a series of articles and Nigerian government sources. A similar approach was used for the surrounding countries' cement industries, for which media articles provided major players in the industry. Additional companies were found by using a Google Maps⁷ search for cement. For each resource, the locations were then validated by using company websites, Google Maps, Wikimapia,⁸ and GIS data sources from the U.S. Geological Survey (USGS).

One of the major sources of spatial data and company identification was *Google Maps*. Searches for materials using Google Maps unveiled various established locations including corporate offices, plants, and mines. Precise coordinates of sites are reliable through this approach; however, the accuracy for smaller-scale company sites were somewhat questionable be-

⁶ www.google.com

⁷ www.maps.google.com

⁸ www.wikimapia.org

cause data was usually limited to a name and a location. If these sites did not represent what they described visually, then the data was disregarded. This method was used for all materials except natural resource deposits, such as aggregates, iron ore, and limestone.

Wikimapia was additionally used to obtain spatial data for plants and mines. Through this method, boundaries of sites are clearly identified using the maps, and this method usually presented more search results than Google Maps. The category of “production” was selected from the menu, which helped filter the points of interest. Similar to Google Maps, precise coordinates were very reliable, but smaller-scale company locations were limited in information and researchers’ judgment was used as to whether data was pertinent to include. This method was used for all materials except aggregates, wood, and RMC.

GIS data resources were used for spatial data of mines, deposits, and (very minimally) for plants. The USGS provided most of this information through a number of databases. The data itself was very plentiful, yet it was deemed unreliable. Many of the locations did not fully reflect what was described by the data. However, due to the number of data points and clusters of points, it was still possible to determine centers of activity. This method was used for all natural resource deposits.

After spatial data sources were exhausted, *company websites* were used to fill in the gaps in data and to find remaining locations of material sites. The amount of information provided on a company website varied significantly. However, almost all of the company websites list corporate offices and a significant portion provided plant locations. A fair number of company websites provide addresses, which were untraceable in Google Maps, and so approximations for locations were made. Other pertinent data was found using these websites, including capacity, quality, product, employees, and power usage. A number of the larger-scale companies produce multiple construction materials; therefore, data overlapped for various construction materials. This method was used for cement, RMC, steel, and some raw material.

Lastly, *material supplier directories* were utilized for additional information. For some directories, such as Cement for cement or Fordaq for timber, this data was reliable but was limited to companies that are a part of the particular collection. Other directories proved to be very unreliable

since many of companies listed may represent another line of work, such as material traders, or they may be out of business. It proved to be impossible to validate this information because company websites or other reliable sources were unavailable. The company addresses listed were also unreliable and varied across multiple directories. This method was used as a last resort, but it was used extensively for timber and somewhat for cement and RMC.

For RMC, an initial collection of factories within Nigeria was located through using any available published resources about the material industry sector. Corporate offices and additional batching plant locations were located through company websites. The office locations were typically available and may even coincide with those in the cement industry. However, most of the data on batching plants was not available or a region was provided for the plant location. Additional plants were found by using a Google Maps search for RMC plants, which provided exact locations for a number of companies.

The determination of aggregate suppliers was made through the Nigerian Mining Cadastre Office.⁹ The source contained information regarding locations where a given company had a mining title.

The wood suppliers were determined through a previously published report regarding the wood industry in Nigeria by Adesogan (2013), “Wooden Materials in Building Projects: Fitness for Roof Construction in South-western Nigeria.” From this report, research was conducted on the individual companies mentioned in the report.

The above method of data collection has a high level of reproducibility and has provided the most current information about suppliers.

2.6.6.2 *Mines and minerals*

Information about raw materials and minerals in the country were investigated using the USGS Minerals Yearbook, which is available for a wide range of countries and has been published in recent years. This method of data collection is highly reproducible.

⁹ www.miningcadastre.gov.ng

The Nigerian Mining Cadastre Office publishes a list of all companies that hold mining titles within the country every year.¹⁰ This data was used to determine where certain companies operate, and what types of materials are in a given region.

Spatial data on mineral resources was partially determined from a series of GIS databases collected by the USGS. Although this data is not recent (newest source from 2008), locations of mines and deposits are not expected to change significantly over the years. Current spatial data on mineral resources, reserves, and exploitation were found through Nigerian government websites.

¹⁰ www.miningcadastre.gov.ng

3 Cement

3.1 Industry

3.1.1 Global scenario

Cement is one of the main constituents of concrete, and it an important contributor to the development of the economy of a country as it contributes to growth and urbanization. Global cement production has been increasing due in part to rising investments in infrastructure in developing countries.¹¹ Cement is mainly a regional commodity because of the variation due to supply-demand differences between regions, per capita income of regions, and level of industrial development per region (Sumaila 2013).

3.1.2 Background

The federal government of Nigeria regulates the country's cement industry. Nigeria's government aims to reduce cement imports to zero by encouraging country self-sufficiency. The cement industry in Nigeria is one of the fastest-growing markets in the world in terms of production capacity and volume. Due to the rapid growth of the industry, cement plants in the country are becoming more sophisticated, resulting in a better quality of product and more of a variety of cement types (Arinze 2015). This expansion and boom is most noticeably seen in the Northern part of Nigeria, near where Maiduguri is located, due to a socio-economic driven country. Along with this, the use of cement within the country has increased dramatically from recent years, leading to additional cement factories throughout Nigeria. The spreading of the cement industry internally has led to competition among manufacturers and distributors, leading to the cement market in Nigeria being completely restructured (Sumaila 2013).

3.1.3 Cement competitiveness

The federal government of Nigeria heavily influences the country's cement industry. Northern Nigerian covers roughly two-thirds of the land space in the country, resulting in a majority of the major cement factories in Nigeria being located in this area. Due to the competitiveness of the market,

¹¹ Britannica Academia, Online ed., s.v., "Cement." Accessed 17 January 2016. <http://www.britannica.com/technology/cement-building-material>

companies are forced to control a certain niche or location of the market in order for the business to thrive and survive (Arinze 2015).

3.1.4 Regionalism

Many industrial considerations to be positioned in the center of a company's market have been motivated by the calculated and planned role of markets in the cement manufacturing process. The cement businesses located throughout the country cannot exist without there being viable markets for them to operate in. This presents a serious concern, as most cement factories in the country are spread throughout the market. As a result, cement companies are devising certain marketing campaigns to properly respond to consumer demand and the ever-changing commercial environment. These marketing strategies develop into an even more crucial role in an increasingly competitive business environment, particularly in developing economies (Arinze 2015).

3.1.5 Cement producers – Nigeria

There are currently six major cement manufacturers in Nigeria: Dangote Cement, Lafarge Group, Cement Company of Northern Nigeria Plc., Bua Cement, Eastern Bulkem Company Limited, and Reagan Renaissance Limited. These companies are located throughout the country, and each company holds a certain amount of the cement market share.

3.1.5.1 Dangote Cement

Dangote Cement has three major cement plants located in Kogi, Benue, and Ibese (Figure 20). These three plants have a current total production capacity of over 20 million metric tons per annum (MTPA). The Obajana Plant, located in Kogi, has the single-largest cement plant capacity in Africa, with a capacity of 10.25 million MTPA. The Obajana plant is energy efficient due to the vertical roller mills for the grinding of clinker and raw material. Figure 21 and Figure 22 more information regarding the Obajana and Ibese plants. Dangote Cement is the only Nigerian company on the Forbes Global 2000 Companies and is the largest-quoted company in West Africa. The company also has cement terminals, or distribution centers, in Lagos, Port Harcourt, Onne, Aliko Inland, and Continental ("Dangote Group").

Figure 20. Locations of Dangote Cement in Nigeria, relative to Maiduguri (Google Maps, 2016).

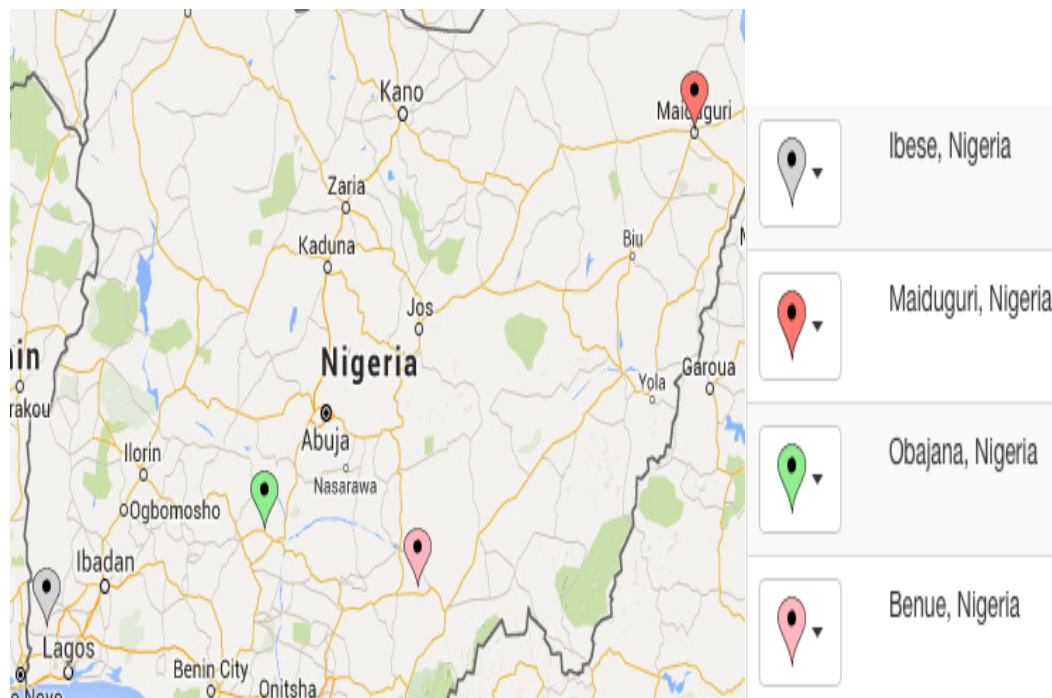


Figure 21. Dangote Obajana Cement Plant information (“Dangote Group: Welcome”).

Key Features

Name of the Plant : Obajana Cement Plant

Location : Obajana, Kogi State Nigeria

Capacity : 2 x 2.5 MTPA + 1 x 6 MTPA of Cement

Raw Material Sources

Limestone : Obajana Mines

Correctives/ Additives : Obajana Mines

Gypsum : Other Sources

Power Source : 3 x 45 MW Captive Power Plant

Fuel Source : Gas, Coal, LPFO

Cement Packing : 8 (L1 & 2) + 10 (L3) Packing machines @ 2400 bags/hr

Cement Loading : 12 (L1 & 2) + 15 (L3) Trucks loading at a time

Figure 22. Dangote Ibese Cement Plant information (“Dangote Group: Welcome”).

Key Features
Name of the Plant : Dangote Cement PLC
Location : Ibese, Ogun State Nigeria
Capacity : 2 x 6000 TPD of Clinker output
Raw Material Sources
Limestone : Ibese Mines
Correctives/Additives : Ibese Mines
Gypsum : Other Sources
Power Source : 3 x 37 MW Captive Power Plant - Bi Fuel
Fuel Source : Gas, Coal, Diesel
Cement Packing : 12 Packing Machines of Capacity 2400 Bags/hr
Cement Loading : 18 Truck Loaders

3.1.5.2 Lafarge Group

The Lafarge Group is a French-based company that operates under multiple names in Nigeria, including Ashaka Cement, Atlas Cement, United Cement Company of Nigeria, and WAPCO Operations.

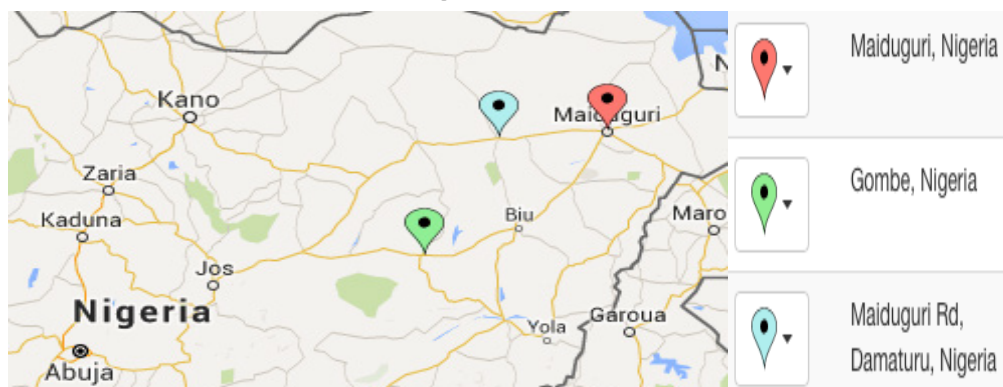
Ashaka cement is located in Gombe, a region in northeastern Nigeria (Figure 23). Ashaka’s cement is widely used in northern Nigeria, and the Nigerian Industry Standard certifies the cement as CEM I¹² (“Lafarge in Nigeria”).

Atlas Cement and the United Cement Company of Nigeria are both subsidiaries of the Lafarge Group who produce both CEM I and CEM II¹³ types of cement (“Lafarge in Nigeria”).

¹² CEM I is a type of cement classification denoting Portland cement without any main addition.

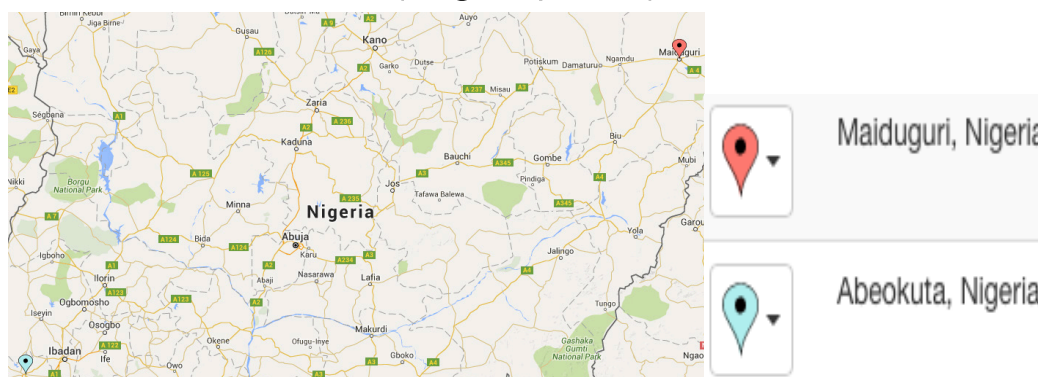
¹³ CEM-II is a type of cement classification denoting Portland cement with low (II/A) to moderate (II/B) content of main addition.

Figure 23. Ashaka cement locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



WAPCO Operations, located in southwestern Nigeria (Figure 24), manufactures a common low-grade type of cement in Nigeria known as “Elephant brand.” The cement is not suitable for structural purposes; rather it is suitable for backfill operations (“Lafarge in Nigeria”).

Figure 24. WAPCO Cement location in Nigeria, relative to Maiduguri (Google Maps, 2016).



3.1.5.3 Cement Company of Northern Nigeria Plc.

The cement company of Northern Nigeria Plc. is located in the far Northwestern region of Nigeria (Figure 25). The company produces Sokoto brand cement in Sokoto, Nigeria. Sokoto cement is certified as CEM II and has a unique quality that makes it the cement of choice for making blocks and for creating plaster. The company has a larger market share in the six states of the Northwestern region, namely: Sokoto, Kebbi, Zamfara, Katsina, Kano, and Kaduna (“Cement Company of Northern Nigeria”).

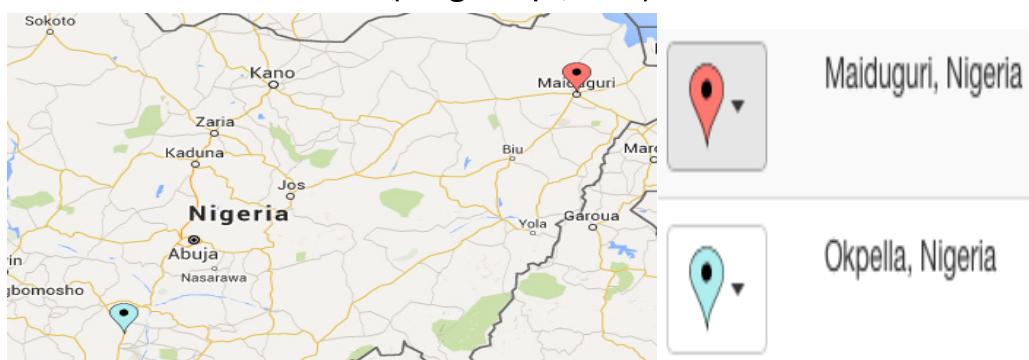
Figure 25. Sokoto Cement location in Nigeria, relative to Maiduguri (Google Maps, 2016).



3.1.5.4 Bua Cement

Bua Cement is located in Okpella, Nigeria (Figure 26). The company produces one of the highest-quality cements available in Nigeria. Although the company is located in the southwestern part of Nigeria, they plan to expand to reach the whole country. Bua Cement also has advanced technology in terms of their clinker conveyor system, clinker silos, feeder units, cement mill, air slides, bucket elevators, cement silos, overhead silos, receiving bins, hoppers, rotary packing and sealing machines, and belt conveyors (“BUA Group”).

Figure 26. Bua Cement location in Nigeria, relative to Maiduguri (Google Maps, 2016).

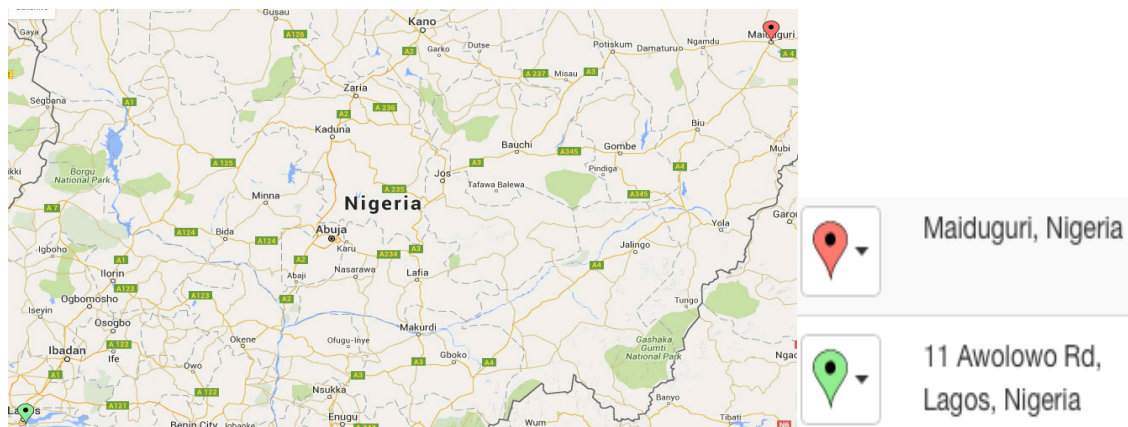


3.1.5.5 Eastern Bulkcem Company Limited

Eastern Bulkcem Company Limited manufactures a common low-grade type of cement in Nigeria known as “Eagle Cement.” The company is located in Lagos, Nigeria (Figure 27). The company produces CEM I, oil well cement, and sulfate-resistant cement. Along with these cement types, the

company has the capability to produce high-strength cement, fly ash cement, low-heat cement, and white cement. The overall capacity for the company is just under 1 million MTPA; however, there are plans in place to expand its capacity to over 1.5 million MTPA (“Welcome to Eastern Bulkcem”).

Figure 27. Eastern Bulkcem cement location in Nigeria, relative to Maiduguri (Google Maps, 2016).



3.1.5.6 Reagan Renaissance Limited

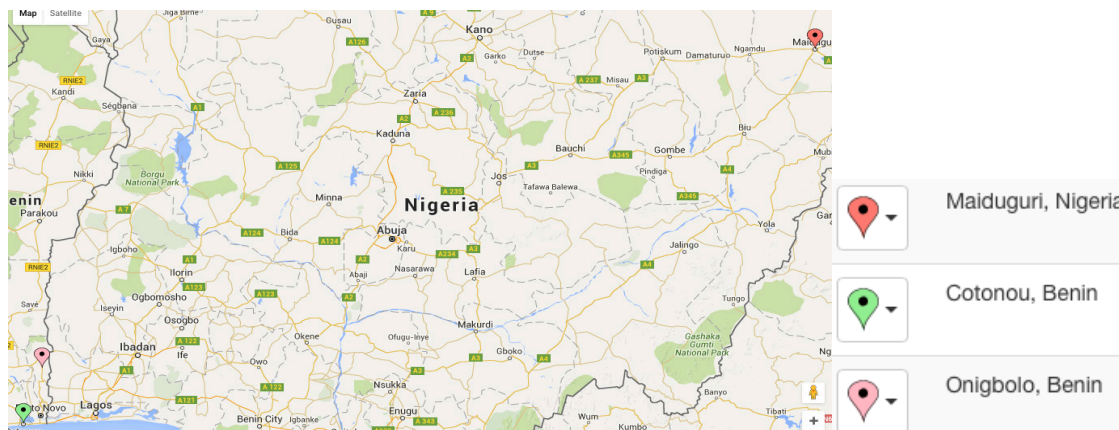
Reagan Renaissance Limited owns and operates Reagan Cement Company Nigeria Ltd. The company is known for their efficient and effective business and marketing strategy that has made them successful since opening in 1998. The company has a packing plant in Calabar with a capacity of 1.2 million MTPA. The company also prides itself in employing a dedicated and highly qualified work force (“Reagan Cement”).

3.1.6 Cement producers – Benin

There are currently four major cement manufacturers in Benin, Africa: Societe des Ciments du Benin (Cotonou), Societe des Ciments d'Onigbolo (Onigbolo), Heidelberg Cement (Cotonou), and Layousse Les Ciments Du Sahel (near Contonou). The various locations are displayed in Figure 28. These companies are located throughout the country, and each company holds a certain share of the cement market (“International Cement Review”).

The four companies produce a lower-grade cement than CEM II; thus, it is concluded that cement from Benin is likely not suitable for structural use.

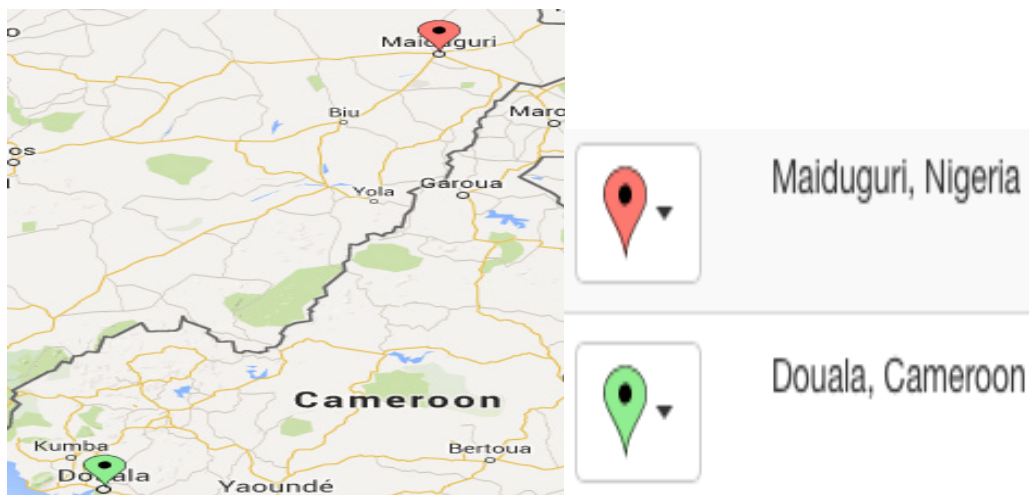
Figure 28. Benin's cement locations, relative to Maiduguri (Google Maps, 2016).



3.1.7 Cement producers – Cameroon

There are currently three major cement manufacturers in Cameroon, Africa: Dangote Cement, Les Cimenteries du Cameroun (CIMENCAM), and Ciments de L'Afrique Cameroun S.A. Figure 29 shows these companies are located around the city of Douala, and each company holds a certain amount of the cement market share (“International Cement Review”).

Figure 29. Cement location in Douala, Cameroon, relative to Maiduguri, Nigeria (Google Maps, 2016).



3.1.7.1 Dangote Cement

Dangote Cement's plant is located in Douala, Cameroon. The plant has a grinding capacity of 1.5 million MTPA. In order to make CEM I, Cameroon must import limestone due to its limited supplies of native limestone.

However, due to the large amount of pozzolanic¹⁴ additives that can be found throughout the country, CEM II is commonly produced at Dangote Cement's plant in Cameroon ("Dangote Group: Welcome").

3.1.7.2 Les Cimenteries du Cameroun

CIMENCAM's plant is also located in Douala. The company is a subsidiary of the France-based Lafarge group, and the plant produces one million MTPA ("Lafarge in Nigeria").

3.1.7.3 Ciments de L'Afrique Cameroun

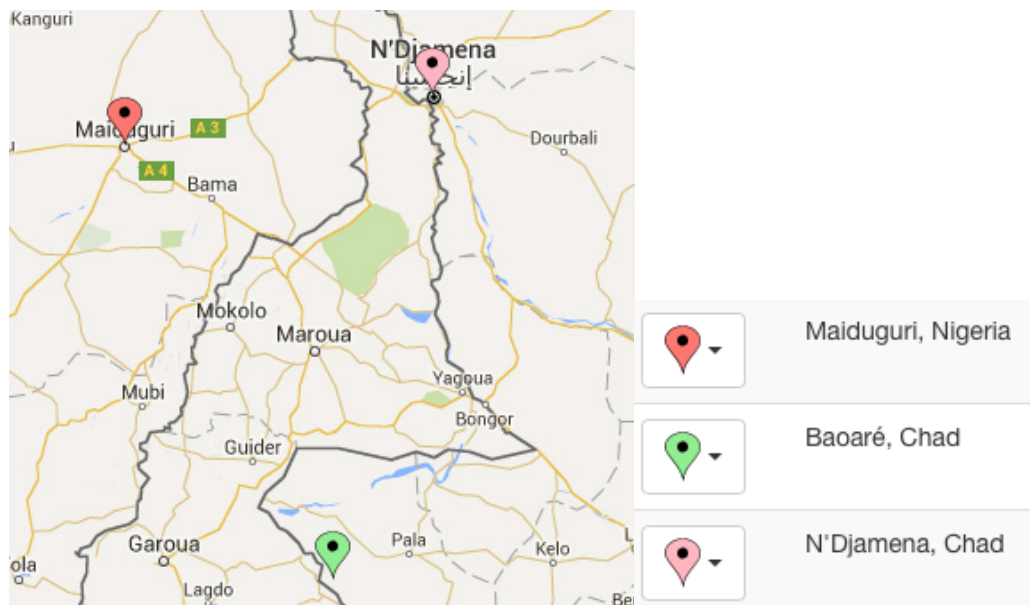
Ciments de L'Afrique Cameroun is a France-based subsidiary company which produces CEM II-grade cement. The cement from this plant is likely not suitable for structural purposes; rather it is suitable for backfill operations ("Ciments").

3.1.8 Cement producers — Chad

There are currently five major cement manufacturers in Chad: Chad Baoare Cement, Ciment de l'Afrique, CIMENTCHAD, Société Nationale de Cimenterie, and Sonacine Usine. These companies are located throughout the country, and each company holds a certain amount of the cement market share. With the exception of Chad Baoare Cement, located in Baoare, the four other cement plants in Chad are located strategically around N'Djamena, the central city of Chad (Figure 30; "International Cement Review"). The five companies produce cement that is similar in grade to CEM II; thus, it is concluded that cement from Benin is likely not suitable for structural concrete use.

¹⁴ A "pozzolan" is a siliceous or siliceous and aluminous material, which in itself possesses little or no cementing property, but will—in a finely divided form and in the presence of moisture—chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Figure 30. Cement locations in Chad, relative to Maiduguri (Google Maps, 2016).



3.1.9 Cement producers – Niger

There are currently two major cement manufacturers in Niger, Africa: Société Nigérienne de Cimenterie S.A. (SNC) and Dangote Cement. These companies are located strategically around the cities of Niamey and Malbaza, and each company holds a certain amount of the cement market share. Société Nigérienne de Cimenterie S.A.

3.1.9.1 Société Nigérienne de Cimenterie S.A.

Société Nigérienne de Cimenterie S.A.'s cement plant was built in 1963 and is located in Malbaza, Niger (Figure 31), which is roughly 450 km east of the capital city of Niamey. Heidelberg Cement, a German-based company, owns and operates the cement plant. The plant has a capacity of roughly 0.04 MTPA; however, the plant only produces about 0.03 MTPA due to various problems ("International Cement Review").

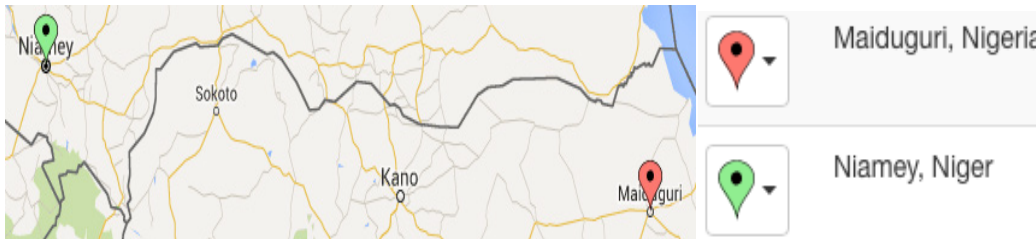
Figure 31. Société Nigérienne de Cimenterie S.A.¹⁵ location in Niger, relative to Maiduguri, Nigeria (Google Maps, 2016).



3.1.9.2 Dangote Cement

Dangote Cement is expanding to Niger, the country neighboring Nigeria's northern border. A cement plant is currently being built in the Niamey region, and it is expected to be complete around mid-2016. The plant is expected to have a production capacity of 1.5 MTPA ("Dangote Group: Welcome"). The plant's location is shown in Figure 32.

Figure 32. Dangote cement location in Niamey, Niger, relative to Maiduguri., Nigeria (Google Maps, 2016).



3.2 Product

3.2.1 Codes, standards, and methods

The government of Nigeria requires concrete and its constituent materials, along with the methods and procedures for concrete to conform to the Nigerian Code produced by The Standards Organisation of Nigeria (SON) (Adewole et al. 2015). This is the lone organization allowed to standardize materials, products, and processes in the country.

The cement codes Nigeria mainly follows are written by SON : "Cement: Part 1-Composition, Specification and Conformity Criteria for Common Cement" (NIS [Nigerian Industrial Standard] 444-1:2003), "Cement: Part

¹⁵ S.A. is a corporate designation that translates to "anonymous society (corporation)."

2-Conformity Evaluation” (NIS 444-2:2003), and “Methods of Testing Cement-Chemical Analysis of Cement” (NIS 445:2003).

The citizens of Nigeria generally do not know nor care about the structural stability of the cement. Rather, they are aware of the different cement types by brand name alone, not the grade or strength classes of the cement (Adewole et al. 2014). Nigerians mostly buy bagged cement, or bagged Portland-limestone cement (BPLC). With the old Nigerian industrial standards, ordinary Portland cement (OPC) was the only type of cement that was allowed to be produced in Nigeria. When the new standards took effect and BPLC began being manufactured, Nigerians were not made aware that BPLC was different than the OPC (Ju and Ifeanyi 2015).

3.2.2 Cement grades

There are three types of cement that are commonly available through the Nigerian open market. Two of these include cement grades 32.5 and 42.5, both of which are used for building construction. Grade 42.5 cements have higher compressive strengths than 32.5 grade cement. Use of the 42.5 grade cement leads to concrete structures that last longer and withstand more loads. Many Nigerians believe that BPLC is OPC because it is what they previously used before materials, such as limestone, began being added as a filler material (Adewole et al. 2014; Ju and Ifeanyi 2015).

3.2.3 Cement types

CEM I is typically used to designate the cement grade 32.5 and 42.5, whereas CEM II is used to refer to BPLC. The CEM I is very similar to OPC; however, CEM II is a cheaper version of CEM I that has limestone added. Cement grade 42.5 represents higher-strength cement than the 32.5 grade (Adewole et al. 2014). CEM I is generally only produced in bulk orders for larger construction companies and projects. Overall, it can be said that the Nigerian CEM I is very similar in quality to Type I Portland Cement in America. Also, CEM II is a lower-quality bagged Portland-limestone cement that essentially is a CEM I with limestone additives (Adewole et al. 2014).

4 Ready-Mix Concrete

4.1 Industry

4.1.1 Global scenario

Concrete is the most widely used construction material throughout the world, and it forms the backbone of many infrastructure systems. The RMC industry began growing significantly in the 1960s, and the industry is expected to expand due to the rising worldwide demand for concrete. The most prominent RMC suppliers in the world are Cemex (based in the United States) and LafargeHolcim (based in Switzerland).

4.1.2 Background

Concrete plants were first established in Nigeria sometime from the 1970s to the 1980s. Since that time, RMC plants have become well established throughout the country, with multiple different companies holding a stake in the industry. In present-day Nigeria, numerous companies own and operate batching plants, truck-mounted rotating drum trucks, and concrete pumps.

4.1.3 Regionalism

Many industrial considerations to be positioned in the center of a company's market have been motivated by the calculated and planned role of markets in the concrete production and distribution process. The concrete businesses located throughout the country cannot exist without viable markets for them to operate in. This presents serious concerns, as most concrete batching plants in the country are spread throughout the market. As a result, concrete companies are devising certain marketing campaigns to properly respond to demand of consumers and the ever-changing commercial environment. These marketing strategies develop into an even-more crucial role in an increasingly competitive business environment, particularly in developing economies (Arinze 2015).

4.1.4 Ready-mix concrete producers – Nigeria

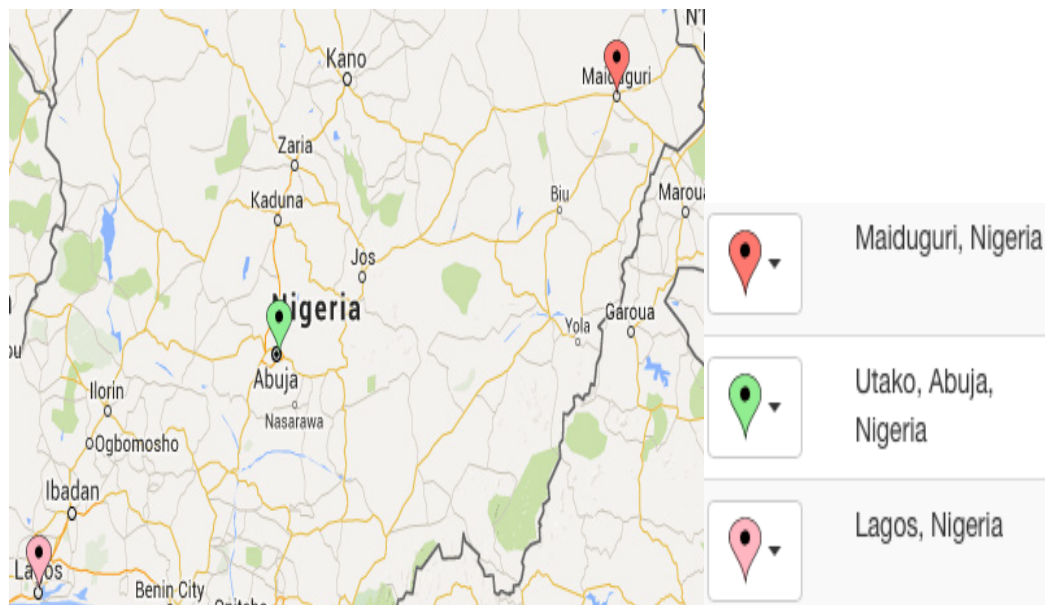
There seven major concrete producers located throughout Nigeria: Julius Berger, Lafarge Africa Plc., Nigerian Concrete Industries Ltd., Ogbebor Concrete Industries Ltd., Quick Mix Nigeria Limited, Sika Group, and SPG Nigeria Limited. There are numerous locations throughout the country

that hand mix concrete for smaller jobs; however these seven companies provide RMC available for purchase. Most of the companies have small mobile batching plants that they relocate near the construction site; however, a few have fixed batching plant locations.

4.1.4.1 Julius Berger

Julius Berger is one of the leading construction companies in Nigeria that offers various construction services. The company has fixed batching plants near Utako and Lagos (Figure 33). The company also follows strict quality-control guidelines to ensure that the concrete produced in their plants will withstand the test of time (“Welcome Julius”).

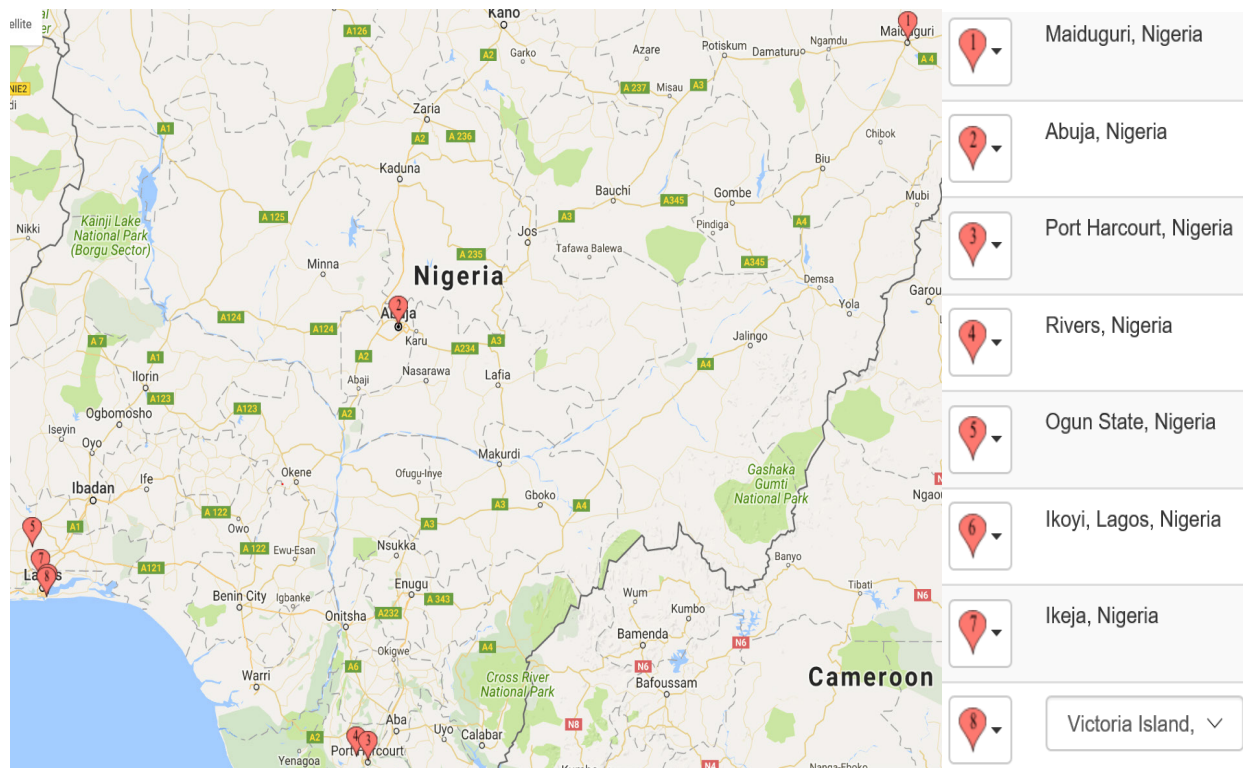
Figure 33. Julius Berger, concrete locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



4.1.4.2 Lafarge Africa Plc.

Lafarge Africa Plc. owns and operates Lafarge Readymix Nigeria, one of Nigeria’s leading concrete manufacturers. The company has a combined seven plants operating in the cities of Abuja, Port Harcourt, Rivers State, Ogun State, Ikoyi, Ikeja, and Victoria Island, with an eight location being the corporate headquarters in Ikeja (Figure 34). Lafarge Readymix Nigeria is the market leader in quality concrete production due to the integrated systems technology the company and its plants utilize (“Lafarge in Nigeria”).

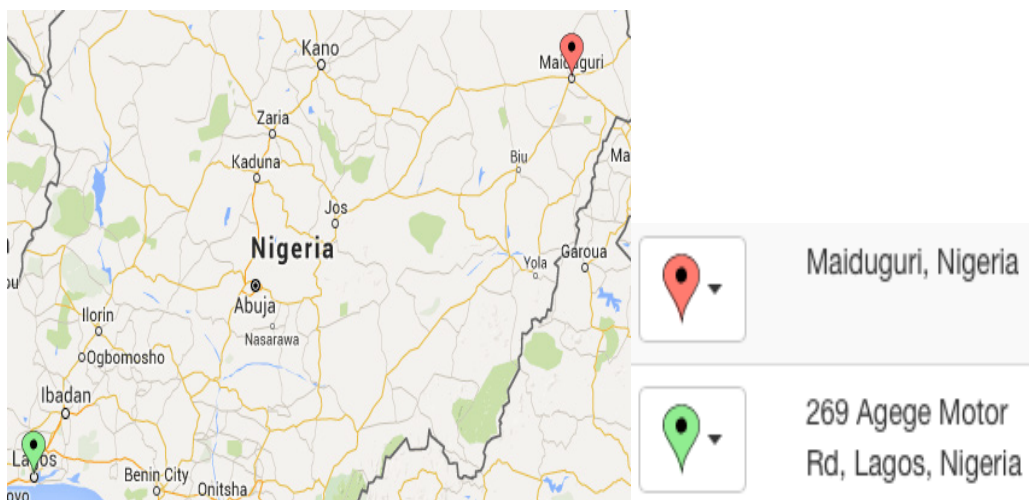
Figure 34. Lafarge concrete locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



4.1.4.3 Nigerian Concrete Industries Ltd.

Nigerian Concrete Industries Ltd. is located in Lagos State (Figure 35). The Nigerian government financed the company's start-up funds. Also, the company is a key contributor to industrial services and business endeavors in Nigeria (Graham 1983).

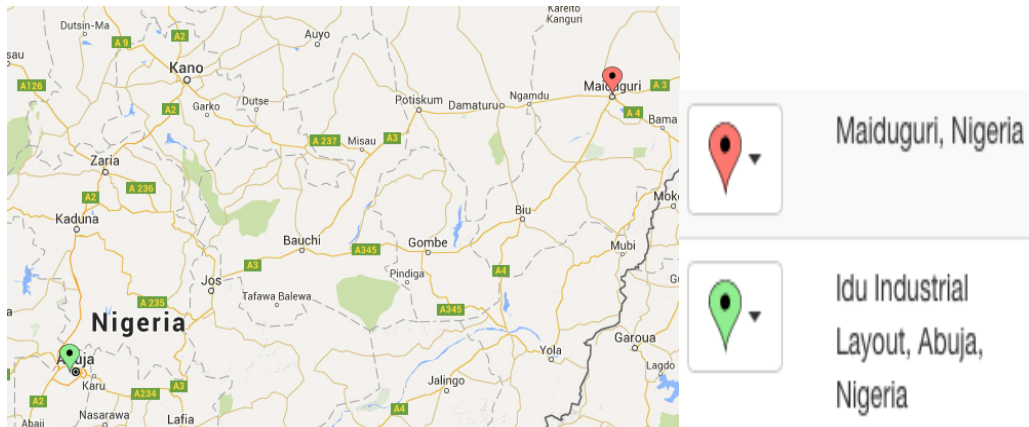
Figure 35. Nigerian Concrete Industries Ltd., concrete location in Nigeria, relative to Maiduguri (Google Maps, 2016).



4.1.4.4 Ogbebor Concrete Industries Ltd.

Ogbebor Concrete Industries Ltd is located in the Idu Industrial Region of the city of Abuja in the Federal Capital Territory (Figure 36). The company is a key contributor to industrial services and business endeavors in Nigeria (Graham 1983).

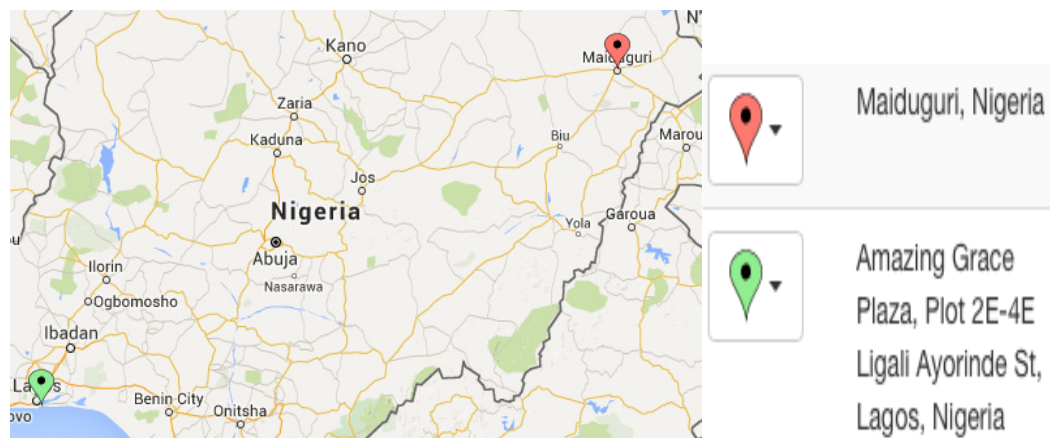
Figure 36. Ogbebor Concrete Industries Ltd., concrete location in Nigeria, relative to Maiduguri (Google Maps, 2016).



4.1.4.5 Quick Mix Nigeria Limited

Quick Mix Nigeria Limited is located in Lagos State (Figure 37). The company has mobile batching plants, which allows them to produce fresh concrete at the job site. The company does not deliver RMC, as they believe fresh concrete offers increased quality. Quick Mix Nigeria is one of the major concrete producers in North and West Africa due to the Holcombe Mixers utilized in their concrete manufacturing processes (“QuickMix”).

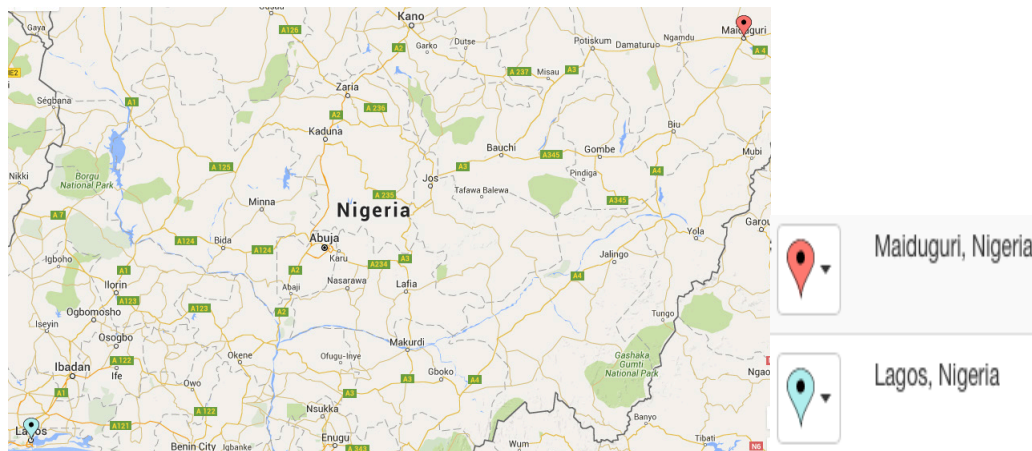
Figure 37. Quick Mix Nigeria, concrete location, relative to Maiduguri (Google Maps, 2016).



4.1.4.6 Sika Group

The Sika Group is worldwide company with locations on almost every continent. Sika Manufacturing Nigeria Ltd. is the Nigerian subsidiary of the company, and their office is located in Lagos (Figure 38). The main function of the company is to manufacture chemical and mineral admixtures for concrete; however, they do produce and supply concrete if needed (“Sika Manufacturing”).

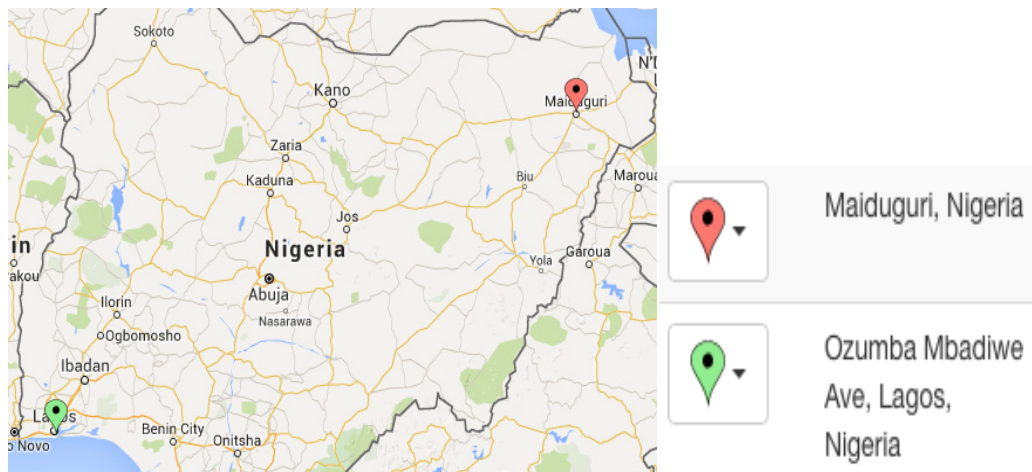
Figure 38. Sika Group, concrete location in Nigeria, relative to Maiduguri (Google Maps, 2016).



4.1.4.7 SPG Nigeria Limited

SPG Nigeria Limited is located in the heart of Victoria Island (Figure 39), and they sell, produce, and deliver quality concrete for customers. The company has new batching plant equipment that is capable of meeting a wide range of production demands (“SPG Nigeria”).

Figure 39. SPG Nigeria Limited, concrete locations (Google Maps, 2016).



4.2 Product

4.2.1 Codes, standards, and methods

The government of Nigeria provides concrete codes and standards through the SON. The relevant Nigerian concrete codes include: – “The Structural Use of Concrete in Building” (Nigeria Code of Practice [NCP] 01:1973) and “Standard Method of Testing Fresh Concrete” (NIS 256:1982). Much of these codes have been written to provide information about placing and testing concrete; however, they also contain small amounts of information regarding methods of manufacturing concrete.

5 Aggregate

5.1 Industry

5.1.1 Global scenario

Aggregate is one of the most available natural resources on Earth. There are coarse and fine aggregate sources located in almost every country. Some regions have a greater amount of coarse or fine aggregate, based on the climate and geography of the region. For example, desert regions contain more fine aggregate (sand) whereas mountainous regions contain more coarse aggregate (stone).

5.1.2 Background

Aggregates used in concrete production are designated either as fine or coarse. Fine aggregates range from 0.001 to 0.25 inch and coarse aggregates range from 0.25 to 1.5 inch. Aggregates are desired to be inert granular materials that are free of impurities. Sands and very finely crushed rocks are typically used as fine aggregate. Coarse aggregate is most commonly gravels or crushed rocks, such as limestone.

For most of the aggregate sources in the country of Nigeria and the surrounding countries, a particular company or organization does not own the aggregate. Rather, in these locations, companies are given mining titles in order to look for and/or use aggregates located in a certain region. With the government giving mining titles, there may be more than one company looking for aggregate in a certain region.

Note: The terms “mine” and “quarry” are used interchangeably in Nigeria.

The main source of data collection for aggregate sources in Nigeria was a list of all companies that hold mining titles in the country, which is an annual list published by the Nigerian Mining Cadastre Office (“Exploration License” 2016). This data was used to determine where certain companies operate and what types of materials are in a given region.

5.1.3 Regionalism

There are numerous unexploited aggregate sources throughout Nigeria and the surrounding countries due to the fact that these countries are still

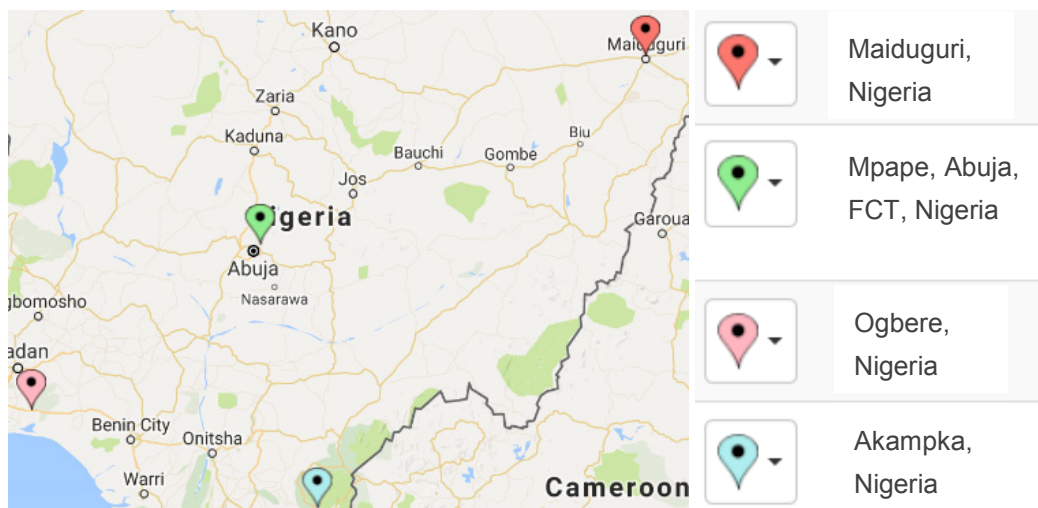
very much developing regions. As a result, the known sources of aggregates are sporadic throughout the region and are most likely near current or recently completed construction projects. Thus, it is expected there are numerous coarse and fine aggregate sources near Maiduguri that have not been documented.

5.1.4 Aggregate sites – Nigeria

5.1.4.1 Julius Berger

Julius Berger is a Nigerian construction company that owns and operates three quarries that are used to extract high-quality aggregate throughout Nigeria. These quarries are strategically located in the cities of Mpape, Ogbere, and Akampka, providing for a variety of customers. The locations of each are presented on Figure 40. The three quarries have a capacity of over five million MTPA. The aggregates produced by Julius Berger meet international standards, and the size of the aggregate can be adjusted for customer needs (“Welcome Julius”).

Figure 40. Julius Berger, aggregate locations in Nigeria, relative to Maiduguri (Google Maps, 2016).

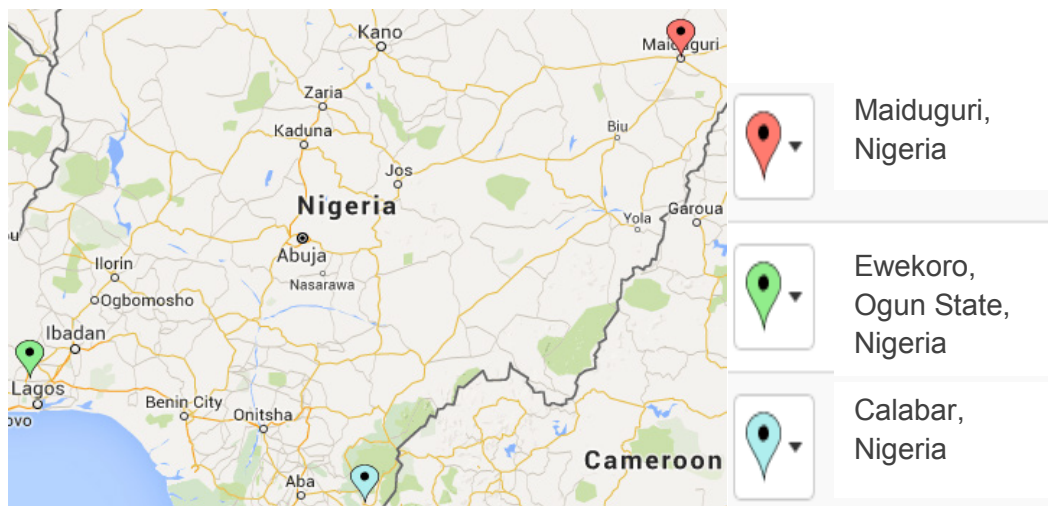


5.1.4.2 Macmahon

Macmahon has quarry locations in Ewekoro and Calabar (Figure 41). The company is contracted by other companies to provide high-quality aggregate for various construction projects. Both quarries produce limestone

aggregate to be used in concrete. In each location, Macmahon has a crushing and sorting capability to provide the highest-quality service for their customers (“Macmahon Holdings”).

Figure 41. Macmahon, aggregate locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.3 Reynolds Construction Company

Reynolds Construction Company (RCC) has three office locations, mainly in southwest Nigeria (Figure 42). The company obtains aggregates from sources nearby their office locations in order to produce quality concrete. Both fine and coarse aggregates are utilized by RCC. The aggregates also meet international standards (“RCC Nigeria”).

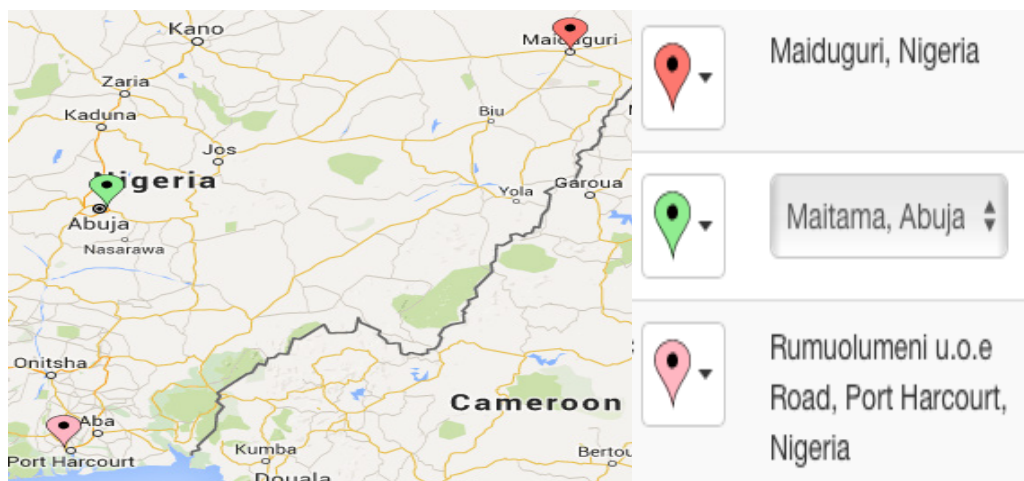
Figure 42. Reynolds Construction Company, aggregate locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.4 PW Group

The PW Group has offices located in the south in Port Harcourt and in the heart of the country near Abuja (Figure 43). Near these locations, the company has quarry sites that have advanced technical equipment available of making very high-quality fine and coarse aggregates. The company has the capability to blast the quarry for the necessary material and to sort the aggregates within a few days in order to meet customer needs (“PW Group”).

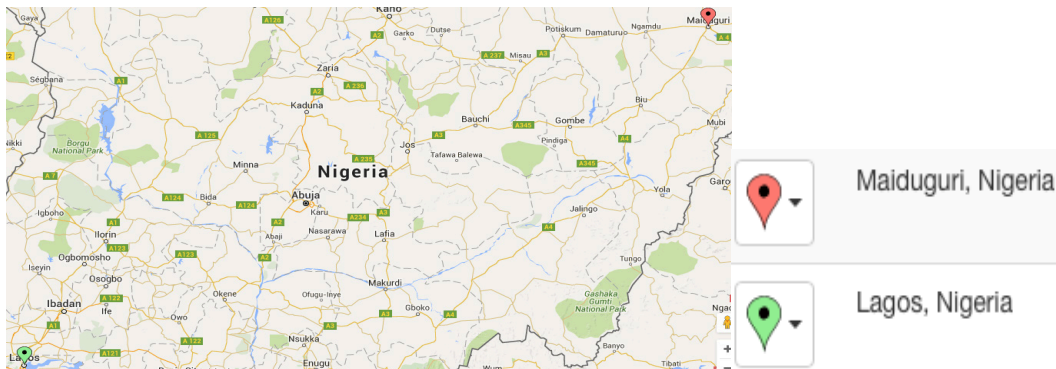
Figure 43. PW Group, aggregate locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.5 Salimonu Company Nigeria Ltd.

Salimonu Company Nigeria Ltd. operates out of the Lagos region (Figure 44), and the company offers quarry materials available for purchase by the public and the government. The company owns and operates its own quarry near its office, and the company has a local delivery service for customers. The company also allows customers to pick up their aggregates from the quarry (“Salimonu Company”).

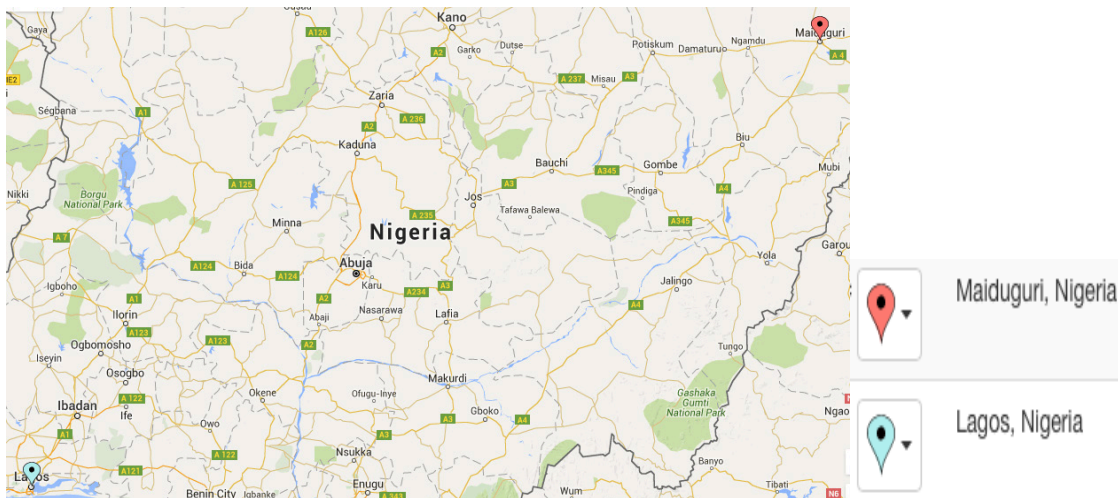
Figure 44. Salimonu Company Nigeria Ltd., aggregate locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.6 Sehnaoui Plant Nigeria Ltd.

Sehnaoui Plant Nigeria Ltd. is a Middle East-based company that operates in the Lagos State in Nigeria (Figure 45). The company owns and operates their own quarries in the area, and the company has the capability to crush, screen, and sort aggregates on site at its quarries. The company also offers a mobile crushing unit that is available to travel to a construction site and crush nearby aggregate for a project (“Sehnaoui Plant”).

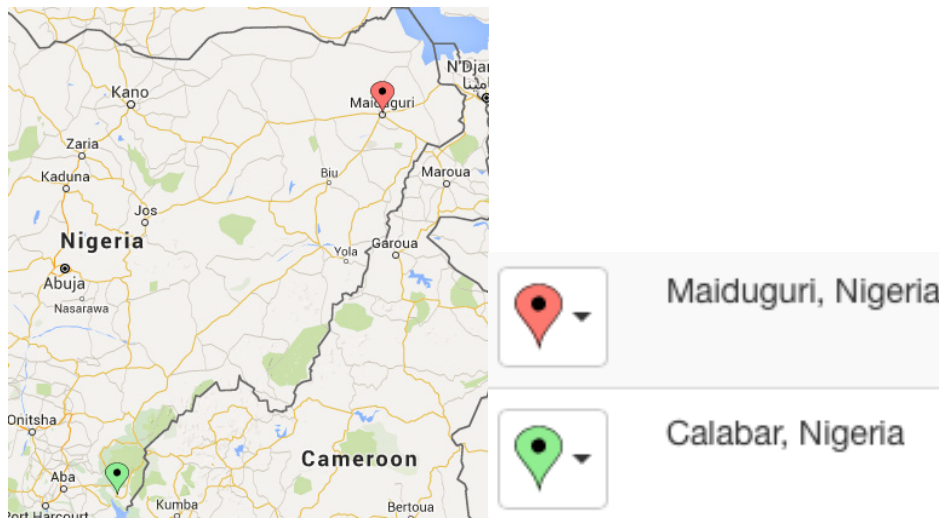
Figure 45. Sehnaoui Plant Nigeria Ltd, aggregate location in Nigeria , relative to Maiduguri (Google Maps, 2016).



5.1.4.7 Ekam Quarry Nigeria Limited

Ekam Quarry Nigeria Limited has a mining title for the region near the Nigerian city of Calabar (Figure 46). Aggregate from this location includes limestone and crushed stone for concrete production (“Ekam Quarry”).

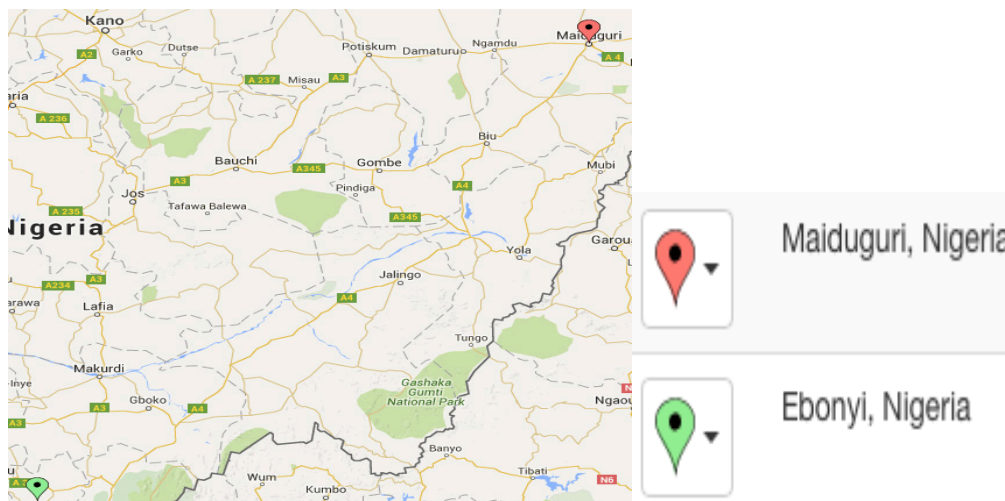
Figure 46. Ekam Quarry Nigeria Limited, aggregate location in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.8 Ebonyi Cement Company

Ebonyi Cement Company owns a mining title for Ebonyi, Nigeria, as shown in Figure 47.¹⁶ The companies mining title allows them to mine limestone from the region. The limestone aggregate from this mine is ground very finely and used for cement manufacturing; however, the aggregates are very high quality. Thus, the limestone aggregate can be crushed to size and be used in concrete production (“Ibeto Group”).

Figure 47. Ebonyi Cement Company, aggregate locations (Google Maps, 2016).

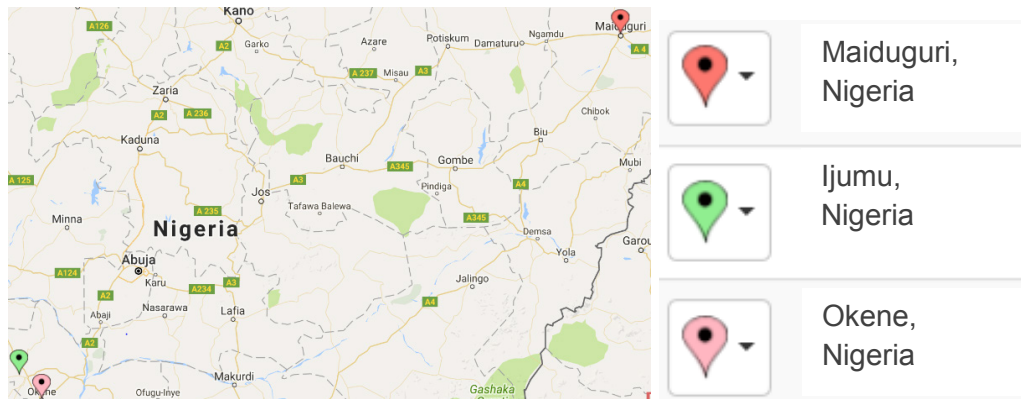


¹⁶ In some instances, a map figure does not show the name of the town (as indicated within the figure’s key) due to the town’s small size.

5.1.4.9 Total Mining Limited

Total Mining Limited has two mining locations in Ijumu and Okene, both in the Kogi State (Figure 48). Both locations have a vast range of mineral resources in the region that are suitable for use in concrete. These minerals include limestone, gravel, sand, and shale, all of which can be used for concrete production (“Welcome to Total Mining”).

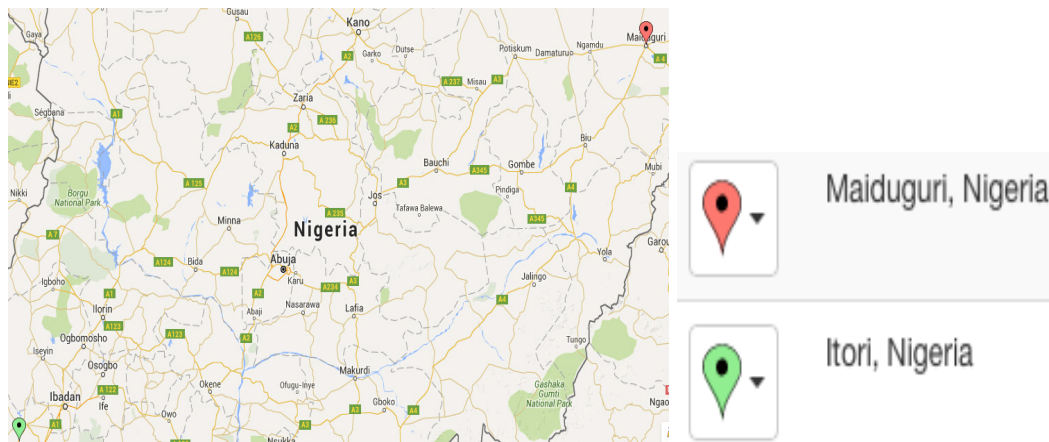
Figure 48. Total Mining Limited, aggregate locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.10 Gateway Mining Company Limited

Gateway Mining Company Limited has a mining title for Ewekoro in the Ogun state (Figure 49). The aggregate from this location includes limestone for concrete production purposes (“Exploration Licence”).

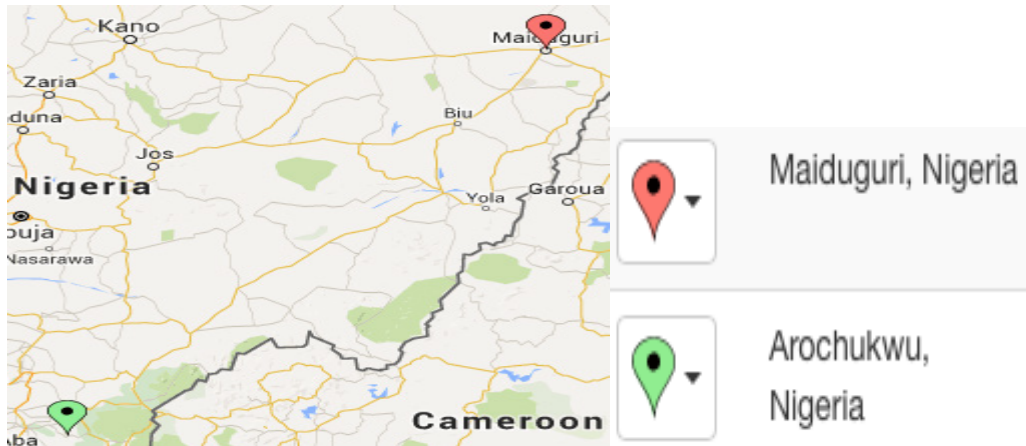
Figure 49. Gateway Mining Company Limited, aggregate locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.11 Reagan Renaissance Limited

Reagan Renaissance Limited mines for aggregate in Arochukwu in Abia State (Figure 50). The aggregates include limestone and larger coarse gravels that are used in cement and concrete production. Clay and sand are also available from the company in the regions around the Kaduna State. The company has international ties to various companies, and they are willing to work with foreign nations in order to achieve success (“Reagan Cement”).

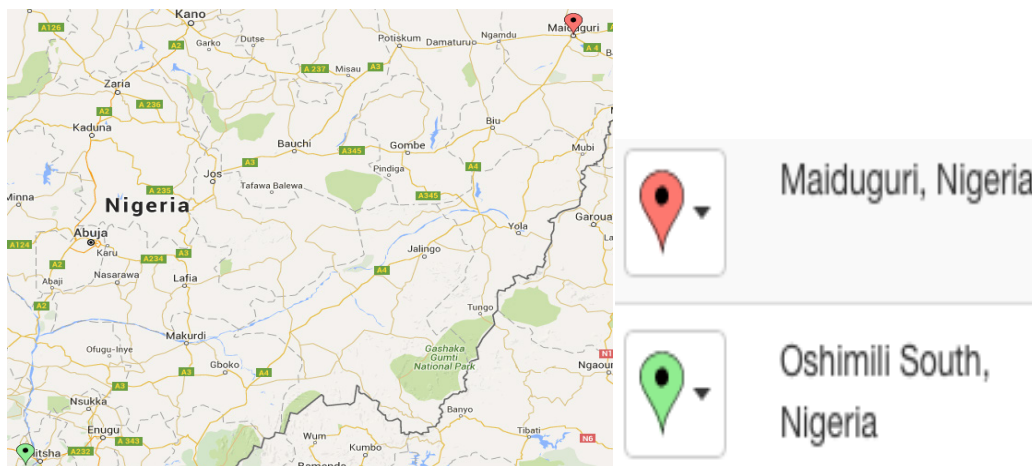
Figure 50. Reagan Renaissance Limited, aggregate location in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.12 GoldenLand Resource International Limited

GoldenLand Resource International Limited has a mining title for Oshimili South (Figure 51). The minerals available in this location include river sand and sand, both of which are suitable for concrete production. The company has offices in Lagos, Abia, and Delta States in order to meet customer needs (“GoldenLand Resource”).

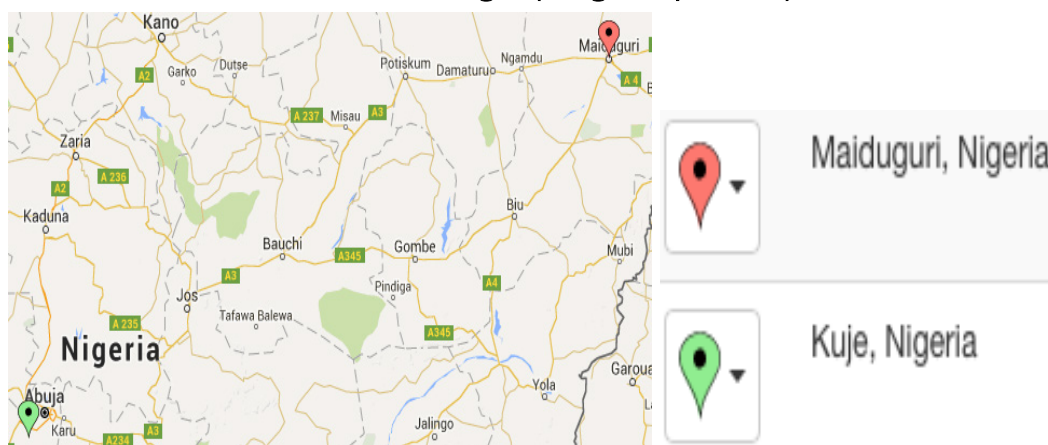
Figure 51. GoldenLand Resources International Limited, aggregate location in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.13 Association of Tipper & Quarry Owners of Nigeria

The Association of Tipper & Quarry Owners of Nigeria has a mining title for the region of Kuje, a local government area within the Federal Capital Territory of Nigeria (Figure 52). The main mineral available in this location is sand, which is suitable for concrete production (“Exploration Licence” and “Extant Grants”).

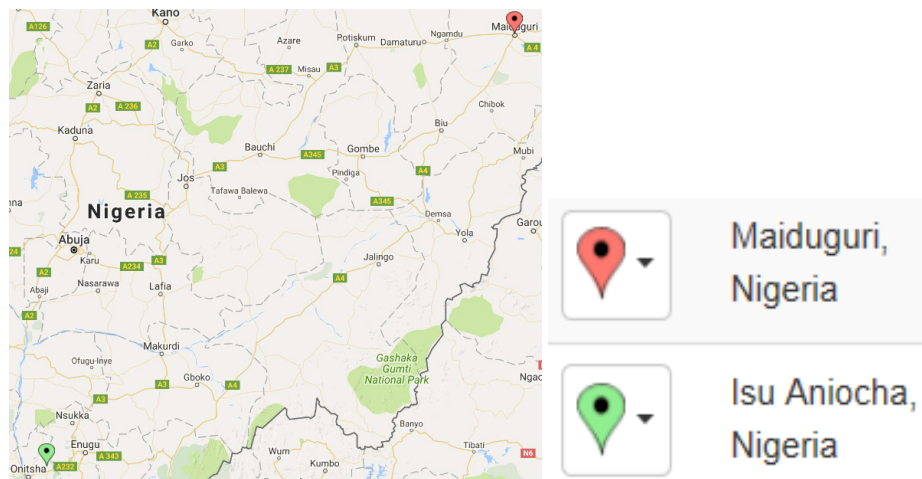
Figure 52. Association of Tipper & Quarry Owners of Nigeria, location in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.14 Anthony Chizea Holding

Anthony Chizea Holding has a mining title for the Delta State in the Isu-Aniocha region (Figure 53). The main mineral available in this location is sand, which is suitable for concrete production (“Exploration Licence”).

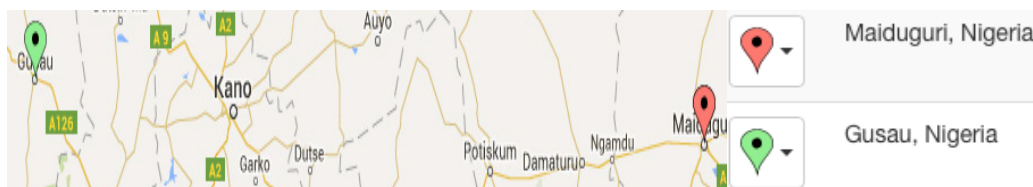
Figure 53. Anthony Chizea Holding, aggregate location in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.15 S. Pawa Quarry

S. Pawa Quarry has a mining title for the Zamfara State in the Gusau region (Figure 54). The main mineral available in this location is sand, which is suitable for concrete production (“Exploration Licence”).

Figure 54. S. Pawa Quarry, aggregate location in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.16 Ratcon Construction Company Limited

Ratcon Construction Company Limited has mining titles for the Ogun, Osun, and Oyo States in the Oluyole region (Figure 55). The main mineral available in this location is sand, which is suitable for concrete production. The company aims to provide high-quality, cost-effective services to meet certain customers’ needs. Along with their mining titles, the company owns and operates five quarries throughout southwestern Nigeria that produce high-quality aggregate. Three of these quarries are located in the Oyo State, one in the Ogun State, and one in the Osun State. The main aggregates that come from these five mines include limestone and granite (“Ratcon Construction”).

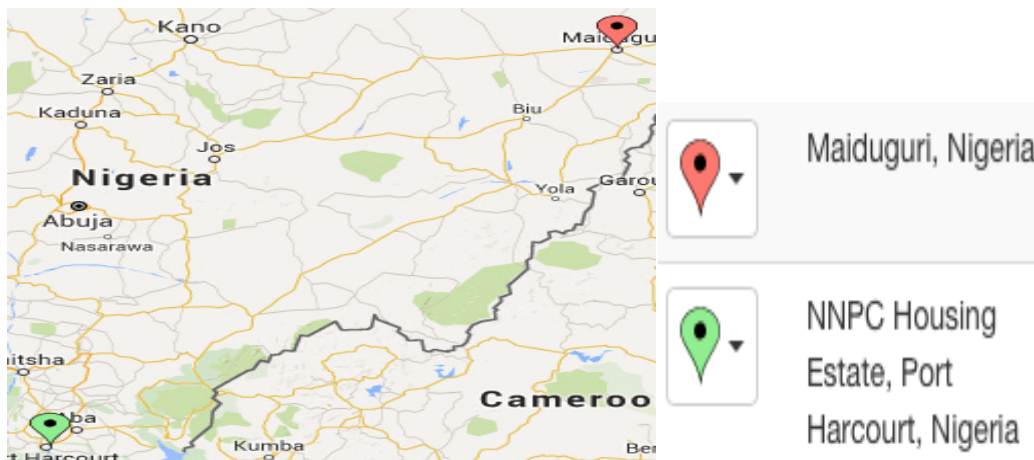
Figure 55. Ratcon Construction Company Limited, aggregate locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.17 M.F.W. Dredging & Marine Nigeria Limited

M.F.W. Dredging & Marine Nigeria Limited has a mining title for the Rivers State in the Akpajo-Elеме region (Figure 56). The main mineral available in this location is river sand, which is suitable for concrete production. The company mainly dredges the nearby waterways in order to obtain the river sand for concrete production. The company aims to meet all international standards to provide the highest-quality service possible (“M.F.W. Dredging”).

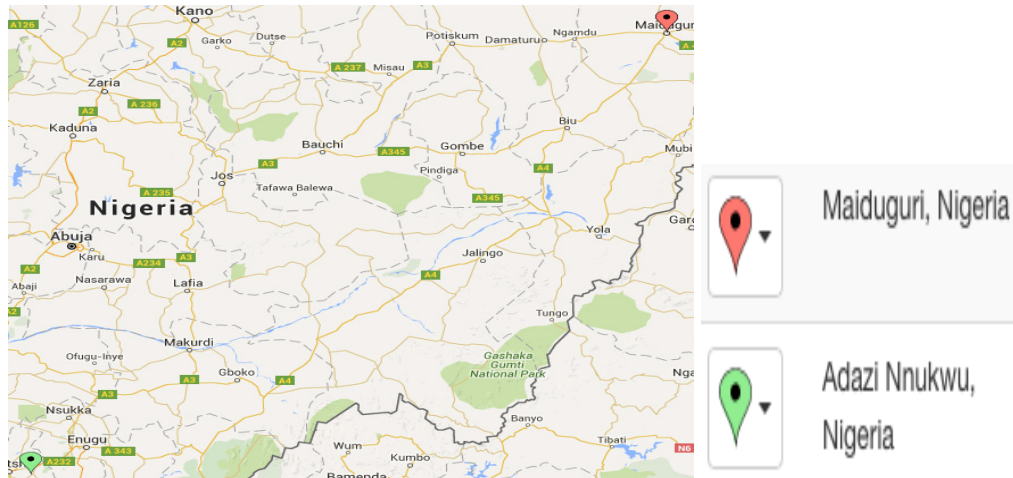
Figure 56. M.F.W. Dredging & Marine Nigeria Limited, aggregate location in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.18 Adazi Nnukwu Town Development Union

Adazi Nnukwu Town Development Union has a mining title for the Anambra State in the Anaocha region (Figure 57). The main mineral available in this location is sand, which is suitable for concrete production. The company is a local organization that has a mining title to obtain the sand they need for their concrete (“Exploration Licence”).

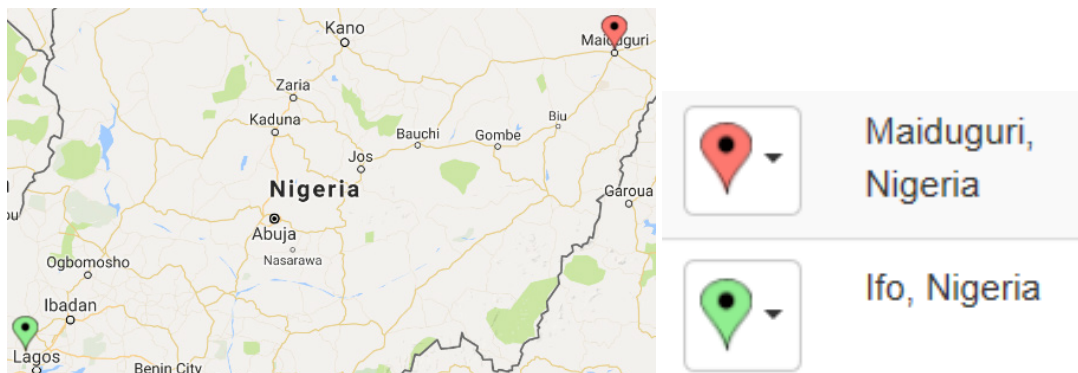
Figure 57. Adazi Nnukwu Town Development Union, aggregate location in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.19 Gateway Holdings Limited

Gateway Holdings Limited has a mining title for the Ogun State in the Ifo region (Figure 58). The main mineral available in this location is river sand, which is suitable for concrete production (“Exploration Licence”).

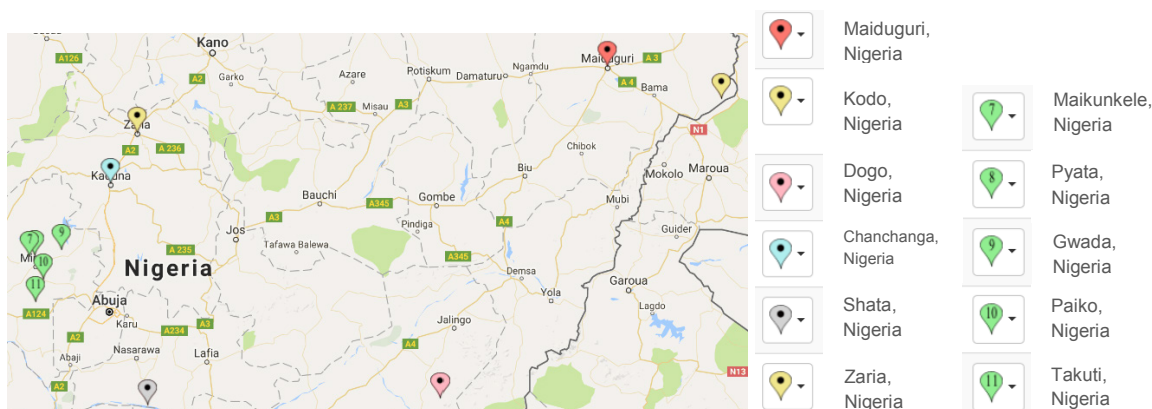
Figure 58. Gateway Holding Limited, aggregate location in Nigeria, relative to Maiduguri (Google Maps, 2016).



5.1.4.20 Various fine aggregate sources

There are various fine aggregate sources throughout Nigeria; however, there are ten areas that have been tested and found to be suitable for concrete purposes: Maikunkele, Chanchanga, Dogo, Kodo, Gwada, Pyata, Shata, Paiko, Takuti, and Zaria. These ten locations are located around central Nigeria (Figure 59) (Abdullahi 2006).

Figure 59. Various fine aggregate locations in Nigeria, relative to Maiduguri (Google Maps, 2016).

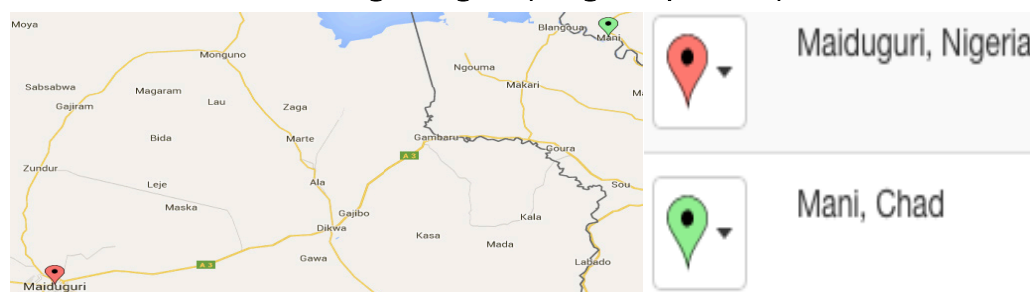


5.1.5 Aggregate sites – Chad

5.1.5.1 Société d'Exploitation Minière de Pala

Société d'Exploitation Minière de Pala owns and operates a quarry in Mani, Chad (Figure 60). The main aggregate available in this location is limestone aggregate, which is suitable for concrete production (IBP 2015).

Figure 60. Société d'Exploitation Minière de Pala, aggregate location in Chad, relative to Maiduguri, Nigeria (Google Maps, 2016).



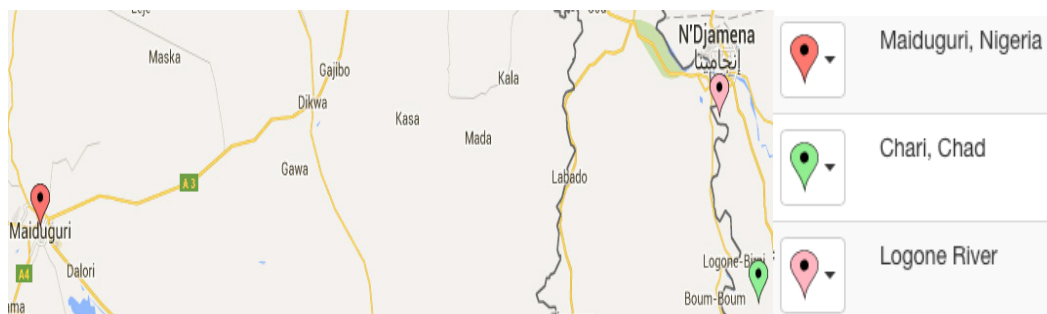
5.1.5.2 Société Tchadienne d'Exploitation des Carrières

Société Tchadienne d'Exploitation des Carrières also owns and operates a quarry in Mani, Chad. The main aggregate available in this location is crushed stone, which is suitable for concrete production (IBP 2015).

5.1.5.3 Various coarse aggregate sources

There are various coarse aggregate sources throughout Chad; however, there are two areas that have been tested and found to be suitable for concrete purposes. The crushed stone aggregate sources in Chad are in the Chari and Logone Rivers regions (Figure 61) (IBP 2015).

Figure 61. Chad, various coarse aggregate locations (Google Maps, 2016).



5.1.6 Aggregate sites – Cameroon

5.1.6.1 Cimencam

Cimencam owns and operates a quarry in Figuil, Cameroon (Figure 62). The main aggregate available in this location is limestone aggregate, which is suitable for concrete production (“Cimencan”).

Figure 62. Cimencam, aggregate location (Google Maps, 2016).



5.2 Product

5.2.1 Codes, standards, and methods

The governments of Nigeria and the surrounding countries involved in the analysis do not have any specific codes or standards for aggregate mining and/or use. The SON provides one relevant code for sampling aggregate: NIS 014: 1974 – “Methods for the sampling and the testing of minerals aggregate, sand and filler.”

Many companies follow the American Society for Testing and Materials (ASTM) standards. The relevant standards include: “Standard Specification for Concrete Aggregates” (ASTM C33/C33M) and “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates” (ASTM C136/136M).

6 Wood

6.1 Industry

6.1.1 Global scenario

Wood is the world's oldest construction material, excluding stone. Roughly 80%–90% of the certified forests are located in the northern hemisphere. Forest certification allows for forest owners and managers to obtain recognition for their forest management practices. Certification is a means to ensure the forest is being used in an environmentally friendly and sustainable way. Approximately 50%–35% of the forests in Europe and North America are certified, respectively. However, less than 0.1% of the forest on the continents of Africa and Asia are certified. Along with this, the world saw a roughly 9% growth of certified forests from 2007 to 2008 (USDA 2010).

The supply of large clear logs for lumber and veneer has decreased through reduction in the use of old-growth forests in North America. Unfortunately, most of the release of stored carbon is due to deforestation in tropical areas around the world. These deforestations lead to these forests being net contributors of carbon to the atmosphere (Shmulsky 2002). In all, approximately 20% of total human-caused carbon dioxide emissions each year are due to deforestation of tropical areas around the world (USDA 2010).

6.1.2 Background

In Nigeria, wood is a very common construction material. It has become an even more valuable engineering material as a result of technological advances in the country. As a result of the large supply of wood in the region, it is used locally and exported to other countries around the world. Unfortunately, the rabid use of wood as a construction material has begun to deplete the local forests. Despite the fact that wood supply levels are decreasing in Nigeria, the fact that wood can be used for many purposes and there are various species, shapes, and sizes available in the country has kept wood at the forefront of construction materials in Nigeria (Ohagwua 2011).

6.1.3 Competitiveness

Wood production and distribution is a highly competitive market in Nigeria; however, the wood industry in Nigeria is progressively deteriorating in performance, efficiency, and productivity. As a result, the industry's competitiveness has decreased starting in the mid-to-late 1900s, but the market is still highly competitive (USDA 2010).

6.1.4 Regionalism

Wood is one of the products in Nigeria that drives the economy. In its prime (1970s and 1980s), forested land covered over 17,000,000 ha of the total land mass in Nigeria. Currently, roughly 9,041,000 ha (9.9%) of the approximately 92,500,000 ha of total land mass in Nigeria is forested. Along with the current forested land, 382,000 ha of previously forested land in the country is now replanted. Still, the amount of forest space has decreased on average by 2.38% (409,650 ha) annually from 1990 through 2010. As a result, 8,193,000 ha (47.5%) of the forest coverage in Nigeria has been depleted in that same time period ("Nigeria Forest Information").

6.1.5 Wood suppliers – Nigeria

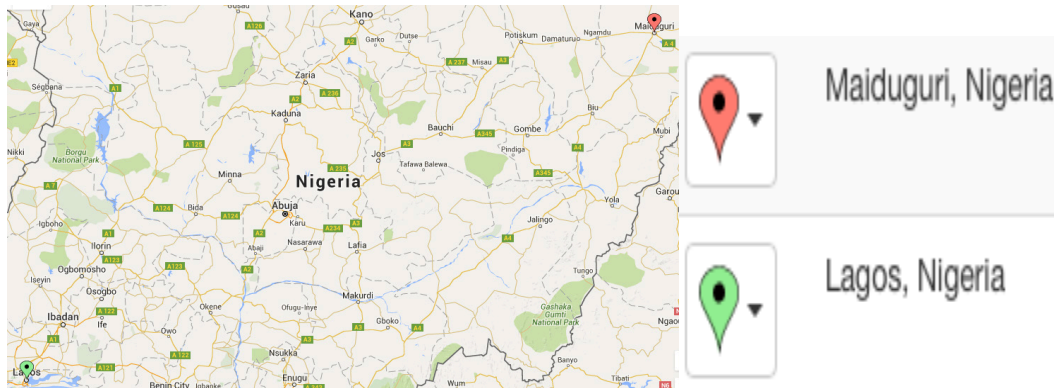
Although wood is still a driving force in Nigeria, due to the decrease in volume of available prime wood species, most of the large wood industries and companies have left the market. The main source of wood in the country is now small-scale companies. As a result of the scale of operation by most companies, their production and distribution is inefficient and wasteful, and they make marginal profits. Many of the small-scale companies lack the money needed to grow and the technology desired to advertise and grow the company. Most of the small-scale forestry companies have a poor quality of products that are produced at a low level of productivity and serve very local markets. To offset many of the disadvantages associated with small-scale wood processing and distribution in Nigeria, it is now necessary that plans be put in place to ensure small companies access to optimal production facilities (Ohagwua 2011).

6.1.5.1 Bayrem Group International

Bayrem Group International owns and operates Bayrem Tropical Timbers based in Lagos, Nigeria (Figure 63). The company is a collection of saw millers and manufacturers. Typically, the company exports wood products; however, they do supply domestically. The company supplies various

types of hardwoods species, specializing in: Iroko, Sapele, African Mahogany/Acajou, Opepe/Bilinga, Red Apa/Doussie, Teak, Gmelina Arborea, Ekki/Azobe, Obeche, and Limba. The hardwood sold by the company is air dried, rough sawn, square edged, and firsts and seconds (FAS)-grade export quality. Bayrem Group International can also plane the material (S4S) and produce tongue and groove, flooring strips, parquet flooring, squares, and pallets upon request (“Bayrem Group”).

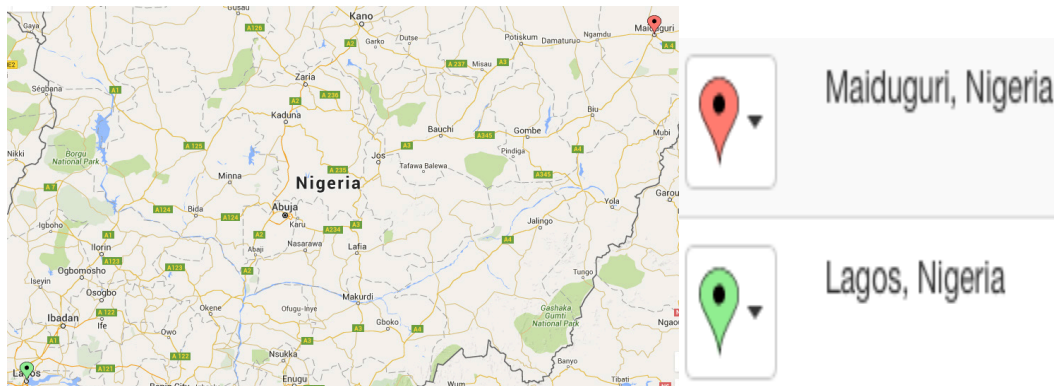
Figure 63. Bayrem Group International, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.2 Bellet Construction Plc.

Bellet Construction Plc is operated from the Lagos State (Figure 64). They buy construction materials in bulk for various construction projects. As a result, the company has various amounts and types of timber available for purchase by the public (“Bellet Construction”).

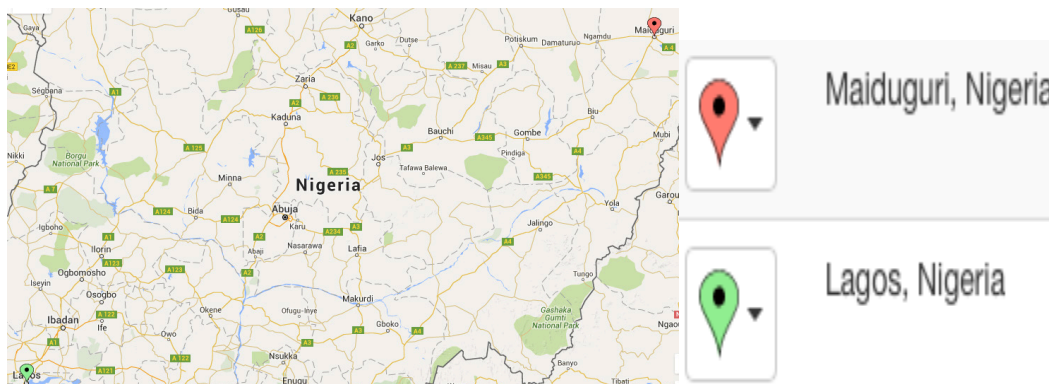
Figure 64. Bellet Construction, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.3 Bissy King International. Ltd

Bissu King International Ltd operates from the Lagos State (Figure 65). The company mainly is in the export business and offers various tropical wood types including mahogany, sapele, teak, gmelina, and iroko (“Bissy King”).

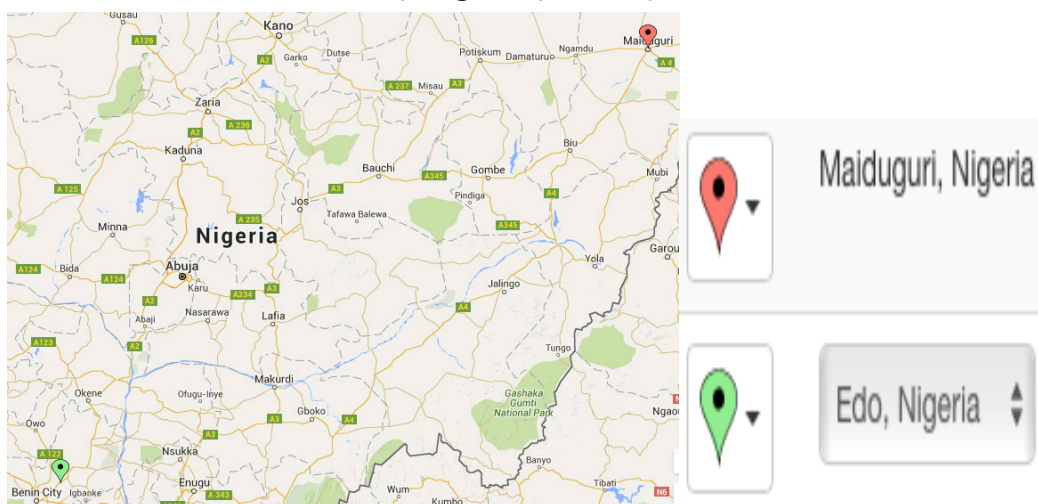
Figure 65. Bissy King International, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.4 Cosource Ventures

Cosource Ventures is a Nigerian company that processes wood and exports various wood products. They are mainly in the furniture business; however, they also manufacture and sell sawn timbers and plywood. Cosource Ventures operates from the Edo State, as shown in Figure 66 (“Cosource Venture”).

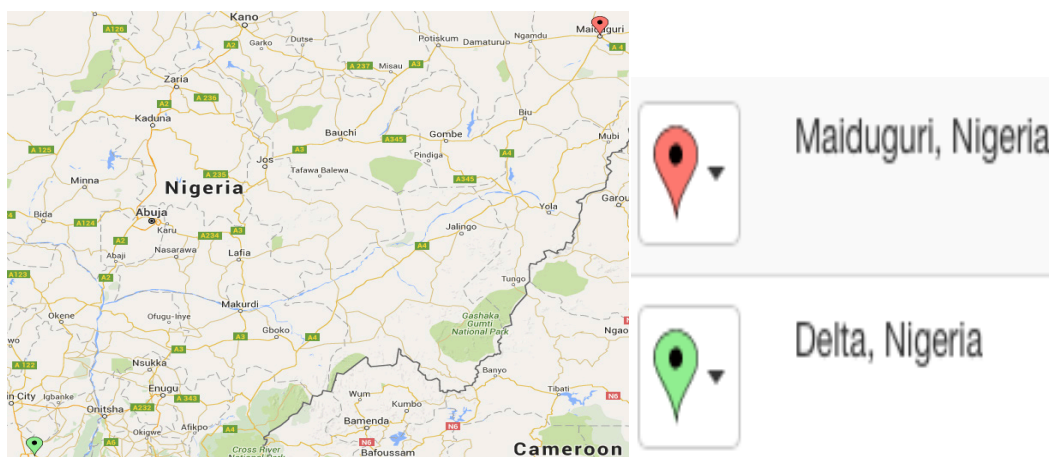
Figure 66. Cosource Ventures, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.5 Delta Forestry

Delta Forestry operates in the Delta State (Figure 67). The company produces exportable timber products, but prides itself in domestic production and manufacturing. The company offers plywood and veneer for purchase by the public (“Delta Forestry”).

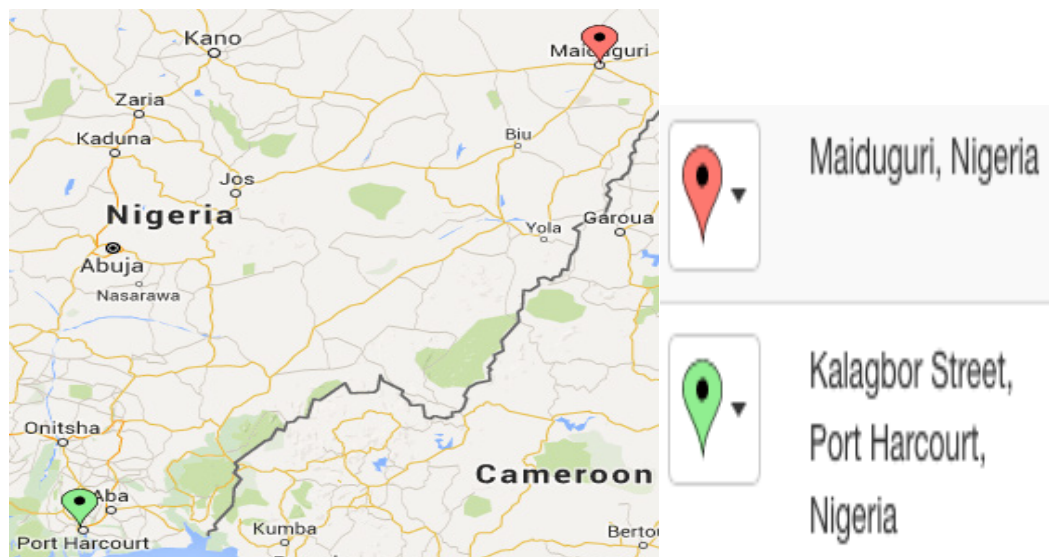
Figure 67. Delta Forestry, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.6 Eddy Bros Nigeria Ltd

Eddy Bros Nigeria Ltd operates from Port Harcourt in the Rivers State (Figure 68). They are a major exporter of African hard plywood, directly from their sawmill (“Eddy Bros.”).

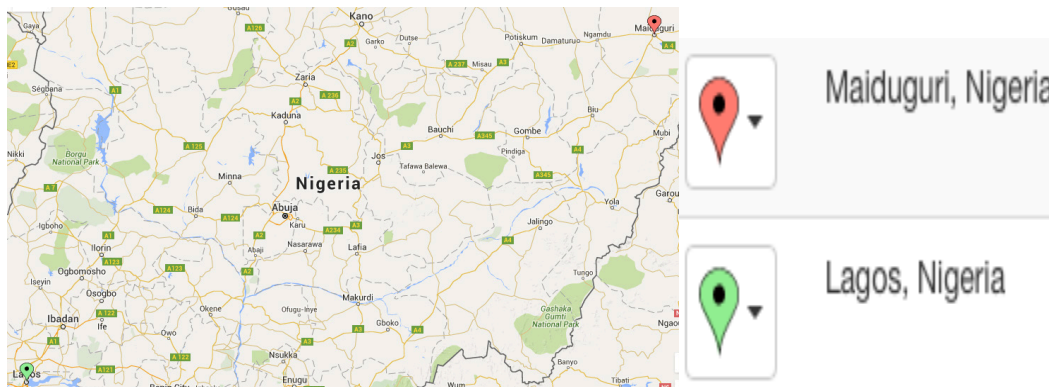
Figure 68. Eddy Bros Nigeria Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.7 EG Woods Ltd

EG Woods Ltd operates out of the Lagos State in Nigeria (Figure 69). They are mainly exporters of swan woods railway sleeper (ekki), obeche, opepe, okan, parquet and particle board, and block board plywoods; however, they do sell some timber types, including red apa and iroko (“EG Woods Ltd” 2016).

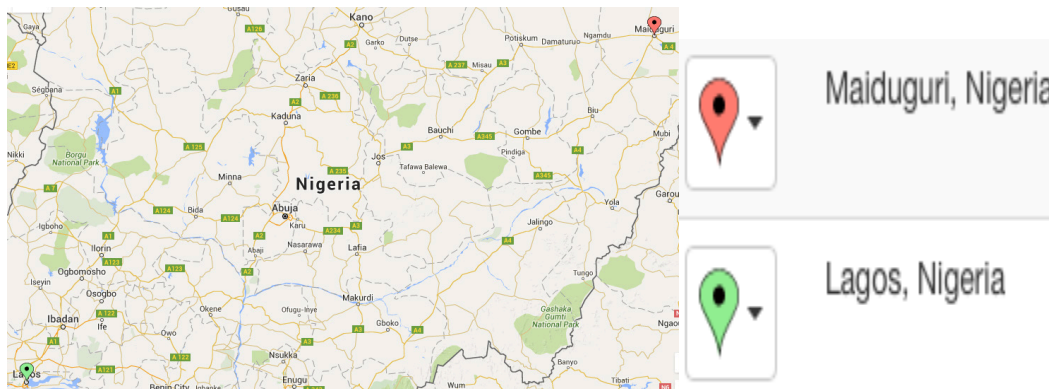
Figure 69. EG Woods Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.8 Hephzibah Resc and Inv Ltd

Hephzibah Resc and Inv Ltd. operates from the Lagos State in Nigeria (Figure 70). The company is mainly in the business of exporting wood from Nigeria; however, they do sell wood domestically. The types of wood sold domestically include iroko, red apa, teak, ebony, and mahogany (“Hephzibah”).

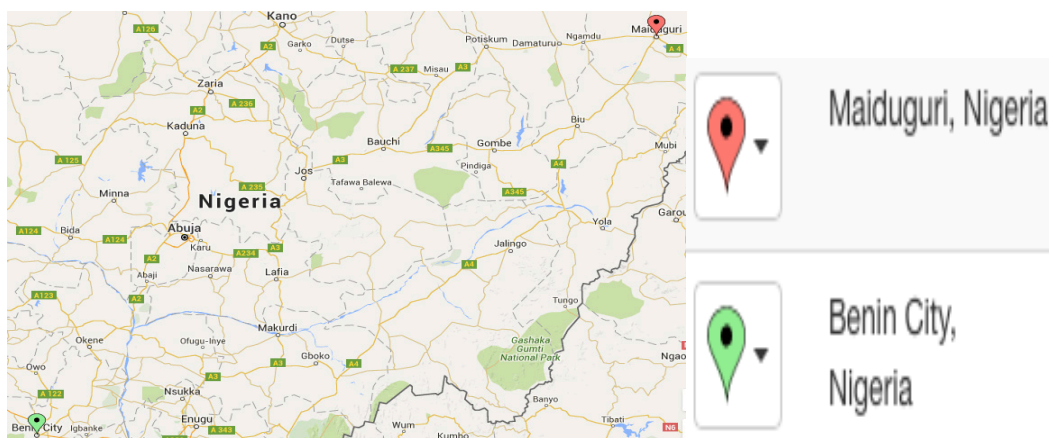
Figure 70. Hephzibah Resc and Inv Ltd wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.9 Jasper Wood Industry

Jasper Wood Industry operates in Benin City in the Edo State in Nigeria (Figure 71). The company is focused on manufacturing furniture products; however, it does offer black alder wood to be purchased by the public (“Jasper Wood Industry”).

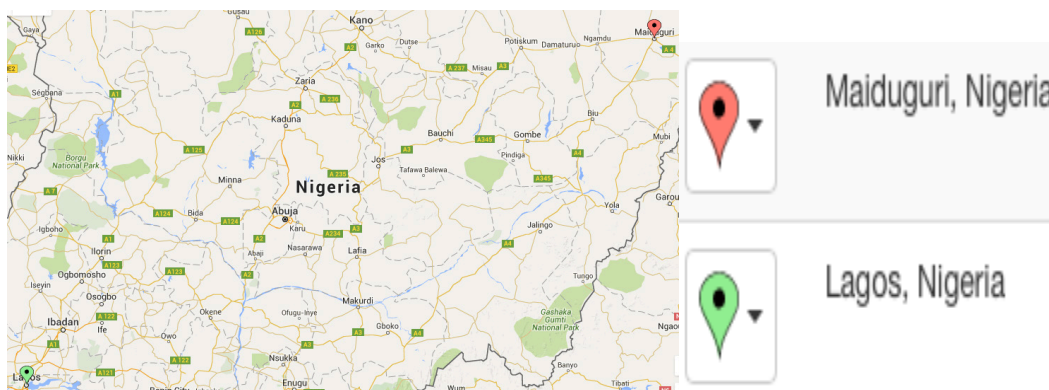
Figure 71. Jasper Wood Industry, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.10 Malagas Ventures Nigeria

Malagas Ventures Nigeria is located in the Lagos State in Nigeria (Figure 72). They offer various forms of hardwood, softwood, and semi and finished wood (“Malagas Ventures”).

Figure 72. Malagas Ventures Nigeria, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).

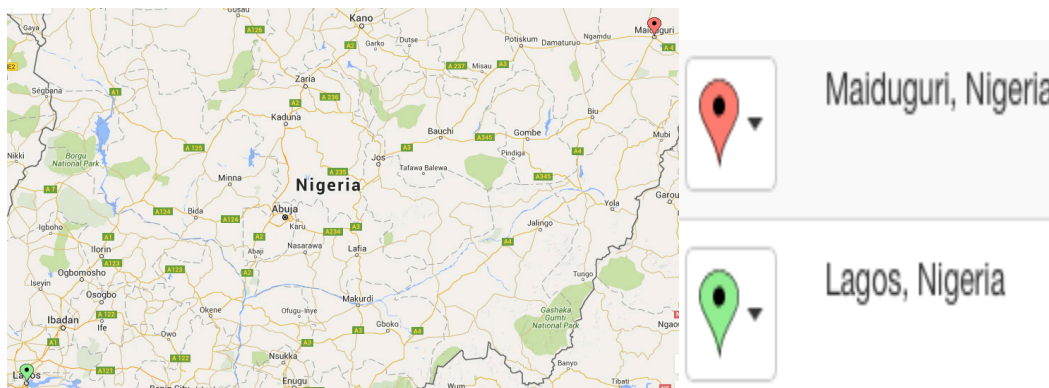


6.1.5.11 Obijiwealth Nig Ltd

Obijiwealth Nig Ltd is a Nigerian-based company, operating from the Lagos State (Figure 73). The company offers various types of woods,

including: Tali (*Erythrophloeum/erun*), Teak Afromexia (*Pterocarpus*), Iroko (*Chlorophora excelsa*), Red Apa (*Afzelia or Doussie africana*), Mahogany (Khaya), Ekki /Azobe (*Lophidra alata*), Obeche/Ayous (*Triplochiton scleroxylon*), Eku (*Brachystegia spp*), Okan (*Cylodiscus*), Sterculia (*Koko igbo*) and, Afara/Frake (*Terminalia superba*) (“Obijiwealth Nig Ltd”).

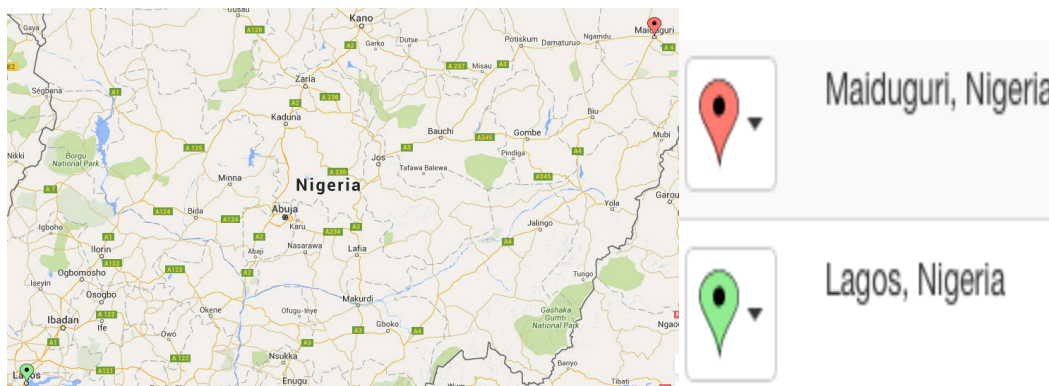
Figure 73. Obijiwealth Nig Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.12 Orlean Farms Ltd

Orlean Farms is located in the Lagos State in Nigeria (Figure 74). The main products they manufacture and distribute include: timber logs, sawdust, and sawn woods (“Orlean Farms”).

Figure 74. Orlean Farms Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).

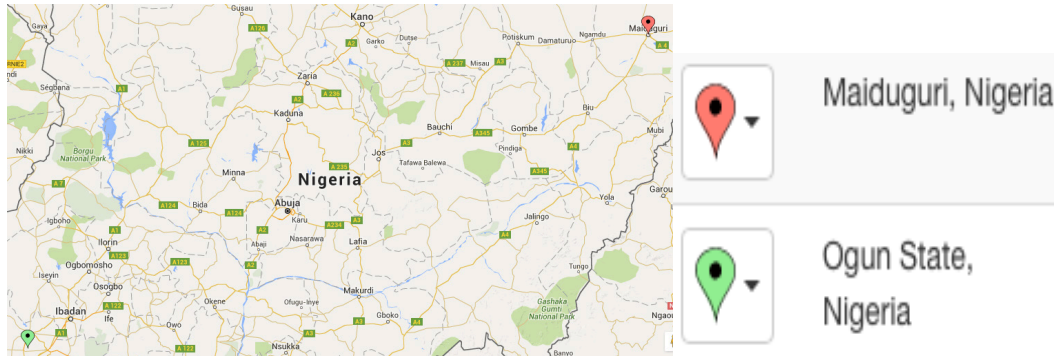


6.1.5.13 Shamen Global Concepts Ventures

Shamen Global Concepts Ventures operates from Ogun State in Nigeria (Figure 75). The company is in the business of producing exotic woods from

all over Nigeria and distributing them domestically and internationally (“Shamen Global Concepts”).

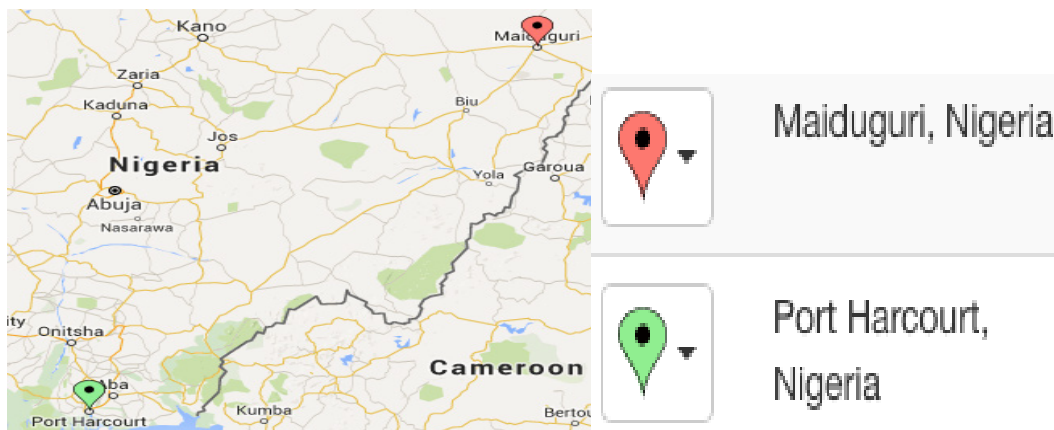
Figure 75. Shamen Global Concepts Ventures, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.14 Shnahan Trading Investment

Shnahan Trading Investment is in the business of selling various wood types, including: alder, aspen, beech, cherry tree, mazonia wood, and tropical timber. The company operates from Port Harcourt, Nigeria, as shown in Figure 76 (“Shnahan Trading Investment”).

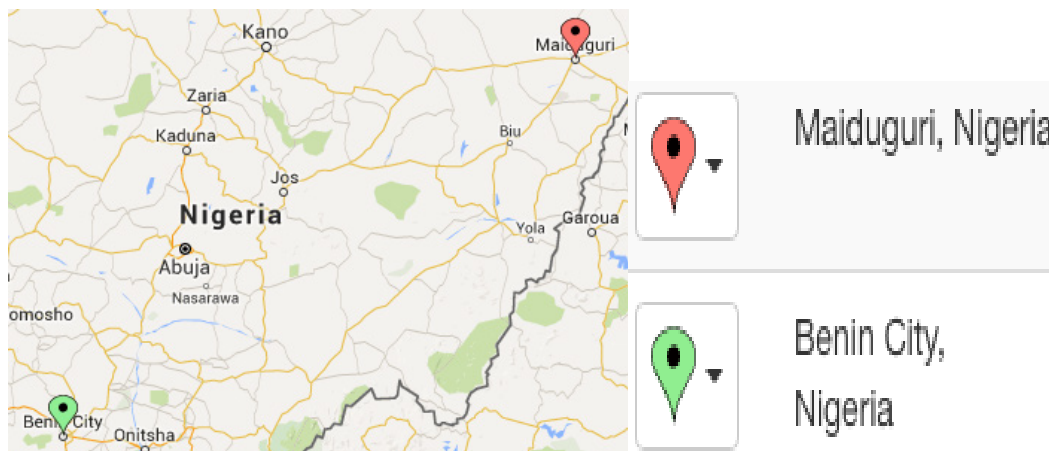
Figure 76. Shnahan Trading Investment, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.15 Stanimose

Stanimose exports Nigerian hard and soft wood in log and sawn forms, including African mahogany. The company does sell locally, if needed. Stanimose operates from Benin in the Edo State, as shown in Figure 77 (“Stanimose”).

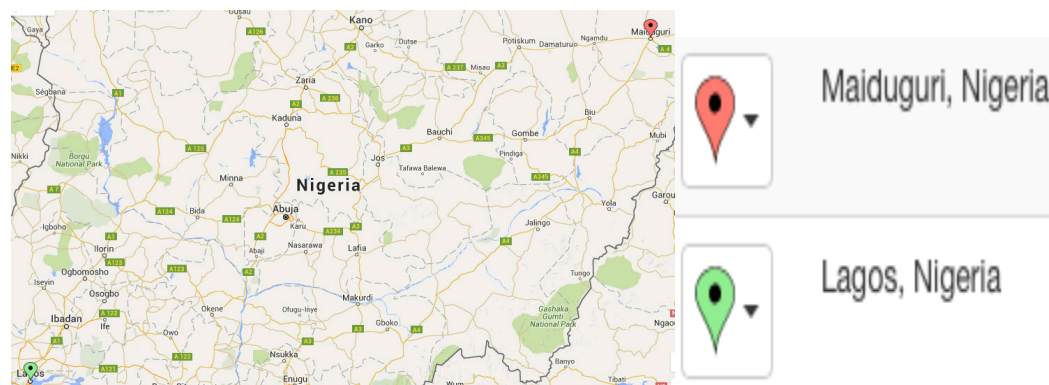
Figure 77. Stanimose, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.16 Tradecorp Investments Nigeria Ltd

Tradecorp Investments Nigeria Ltd operates from the Lagos state in Nigeria (Figure 78). The company manufactures and distributes parquet and wooden flooring. Apple (*pyras malus*) is one of the main wood types the company distributes (“Tradecorp”).

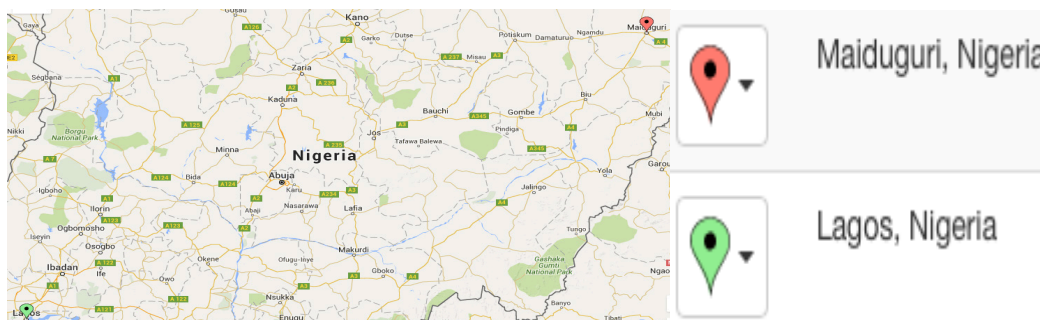
Figure 78. Tradecorp Investments Nigeria Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.17 Ulman Investment Nig Ltd

Ulman Investment Nig Ltd operates from the Lagos State in Nigeria (Figure 79). The company has a full forest of teak wood that can be sawed and manufactured to client specifications (“Ulman Investment”).

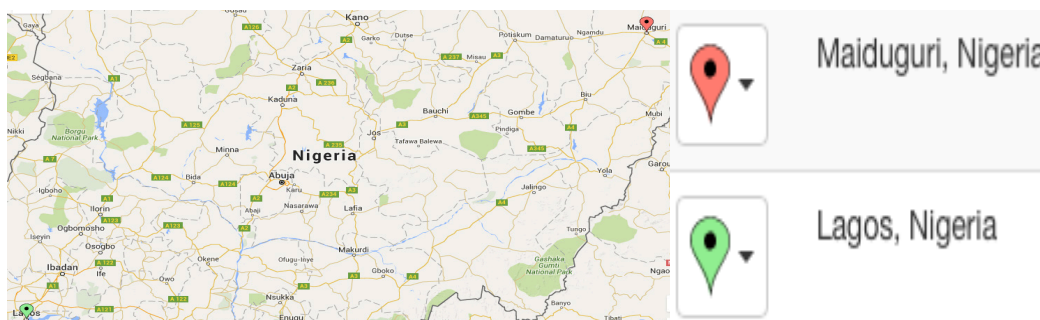
Figure 79. Ulman Investment Nig Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.18 Wood'vantage Ltd

Wood'vantage Ltd is a Nigeria-based company that operates from the Lagos State (Figure 80). The company manufactures and distributes various types of plank, sawn wood, sawdust, and wood chips and bark ("Wood'vantage").

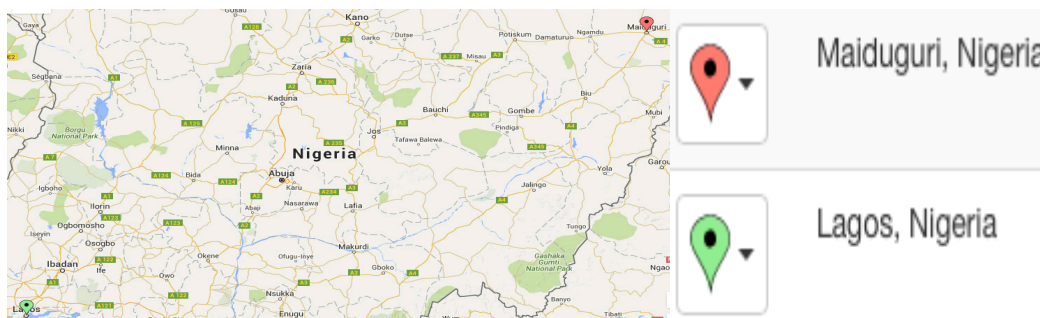
Figure 80. Wood'vantage Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.19 Yemi Productions Ltd

Yemi Productions Ltd operates from the Lagos State in Nigeria (Figure 81), and the company offers various types of Nigerian tropical wood for purchase by the public ("Yemi Productions Ltd").

Figure 81. Yemi Productions Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.20 Nigerian-Romanian Wood Industry

Nigerian-Romanian Wood Industry (NIROWI) is a joint venture between Nigerian and Romanian organizations. From Nigeria, the organizations are: the Federal Government of Nigeria, Beeb Holdings Limited, Nigerian Industrial Development Bank, Nigerian Bank for Commerce and Industry, and the Local Governments of Ondo and Ekiti States. FOREXIM of Romania is the Romanian partner, and they focus on the technical aspect of the company. The main Nigerian office is in the Ondo State of Nigeria. The company operates in many different product areas, including: sawmilling, forest exploitation, and plywood, veneer, furniture, and particle board factories. The company also has the following state-owned mechanized subsidiaries in Nigeria:

- Seromwood Industries Limited (located in city of Calabar)
- Calabar Veneer and Plywood (located in city of Calabar)
- Nigeria-Romanian Wood Industry (located in Ondo State)
- Epe Plywood Company Limited (located in Epe, Lagos State)

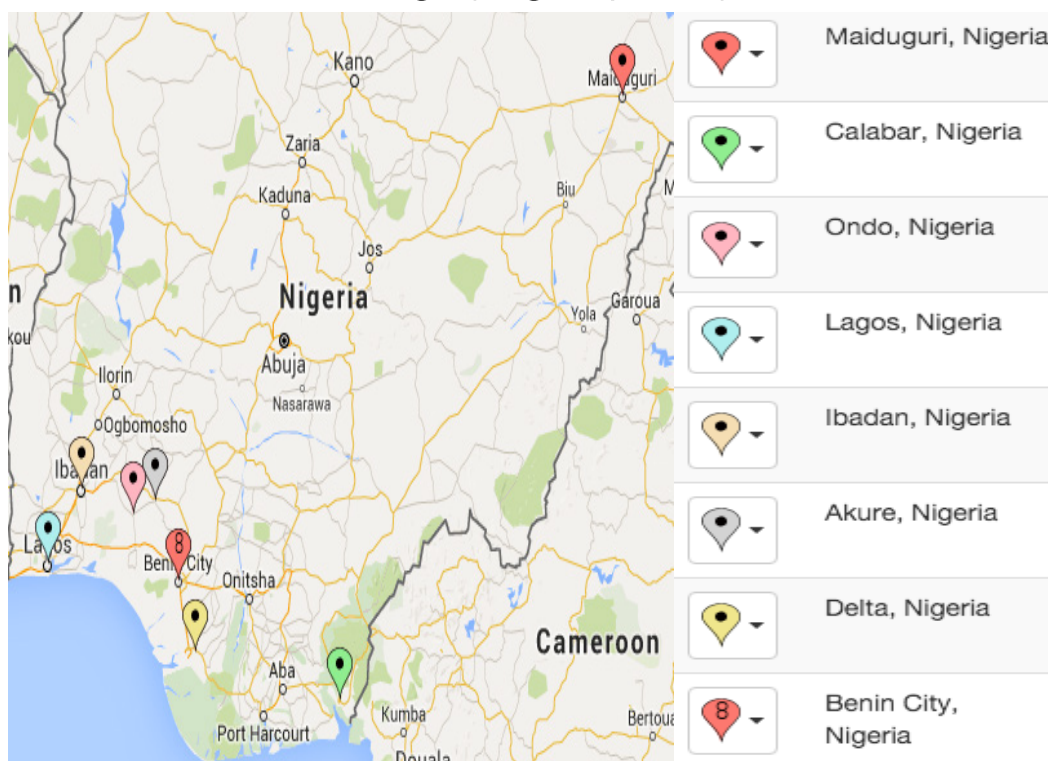
Along with the above state-owned mechanized subsidiaries, NIROWI controls various mills in the region, including:

- Amo Sawmills (located in city of Ibadan)
- Olukayode Sawmill (Nig) Limited (located in city of Akure)
- Soarse Wood & Timber (located in city of Akure)
- Premier Timber Industries (Nig) Ltd (located in Bolurundoro and the city of Akure)
- NIROWI (located in Ondo State)
- Omoniyi Sawmill (located in city of Akure)
- African Timber & Plywood (located in Sepele, Delta State)

- Iyayi Group of Companies (located in Benin City)
- Calvenwood Veneer & Plywood (located in city of Calabar)
- Wood Complex Ltd (located in city of Calabar)
- Eastern Match Industries (location not provided)
- Woodland Timbers (located in city of Lagos)

The various locations of NIROWI are displayed in Figure 82. No further information (e.g., capacities, wood types) was provided for the state-owned mechanized wood industries or mills that NIROWI owns and operates (“The Impacts of Forest”).

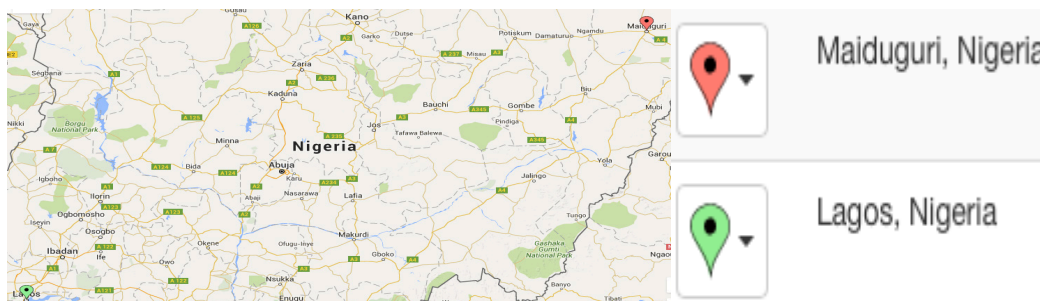
Figure 82. Nigerian-Romanian Wood Industry, wood locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.21 Epe Plywood Industries Limited

Epe Plywood Industries Limited is a major wood processing country in Nigeria that produces plywood, flush doors, veneer, and furniture. The company is located in the Lagos State (Figure 83), and it is jointly owned by Odu'a Investment Company Limited and Bank of Industry (“Epe Plywood”).

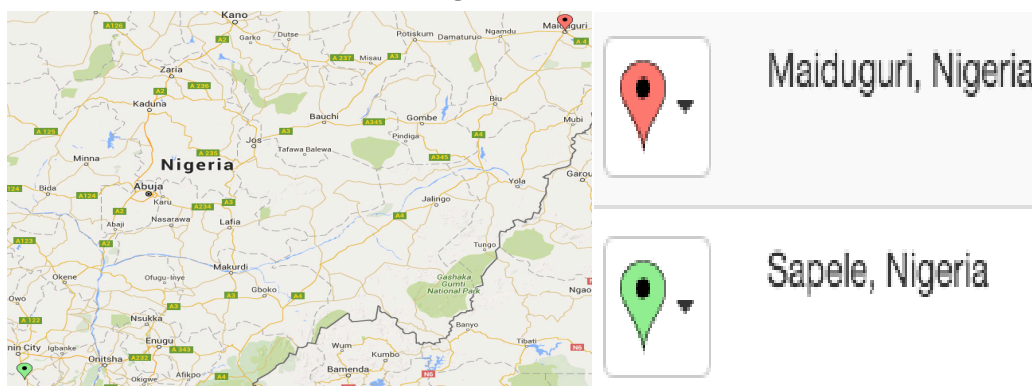
Figure 83. Epe Plywood Industries Limited, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.22 African Timber and Plywood

African Timber and Plywood is located in the Sapele, a town in the Delta State (Figure 84). The company focuses mainly on plantation forestry maintenance, harvesting, processing, and utilization. The company has large plyboard mill and sawmill sectors that allow it to thrive in the market (Okunomo and Achoja 2010).

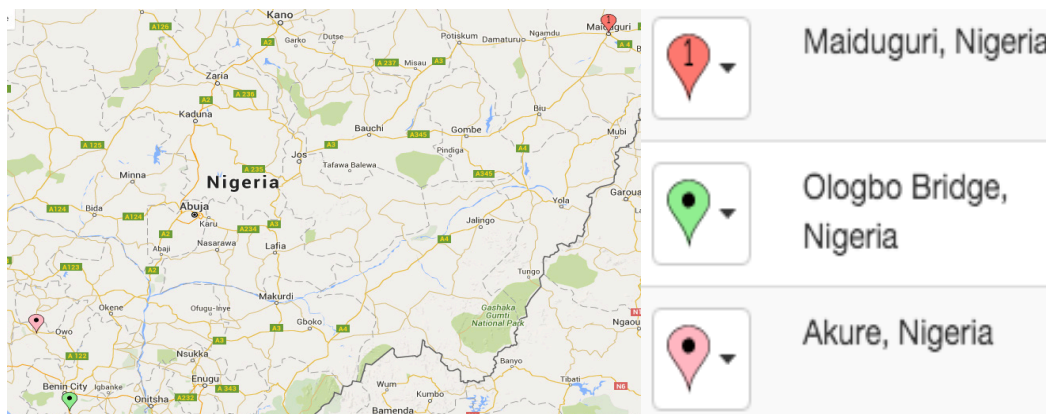
Figure 84. African Timber and Plywood, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.23 Piedmont Plywood

Piedmont Plywood is a Nigeria-based company that operates from two locations: the main office in Ologbo Bridge and a secondary location in Akure, both of which are shown in Figure 85. Through its two locations, Piedmont Plywood is one of the largest operational sawmills in Nigeria (“Review and Improvement”).

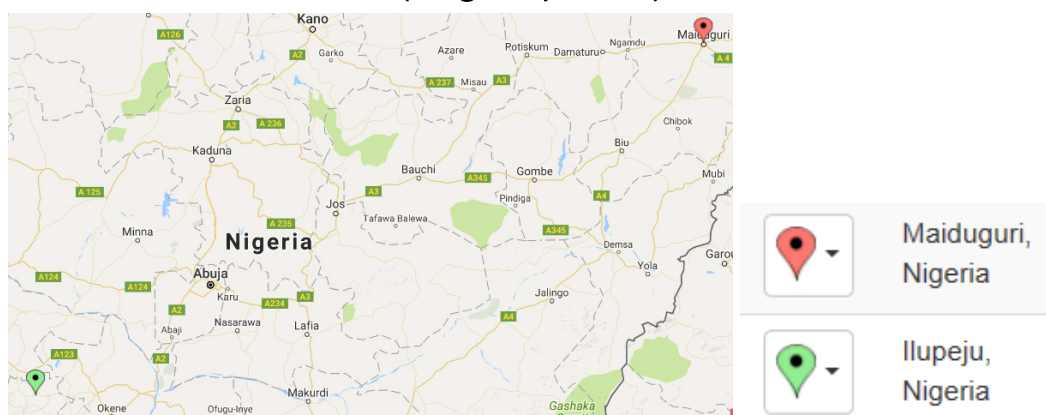
Figure 85. Piedmont Plywood, wood locations in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.24 Aframero Limited

Aframero Limited is a Nigeria-based company operating in Ilupeju in the State of Lagos (Figure 86). They specialize in distributing within the country and sell Africa tropical wood to be used for construction purposes (“Fordaq: The Timber Network”).

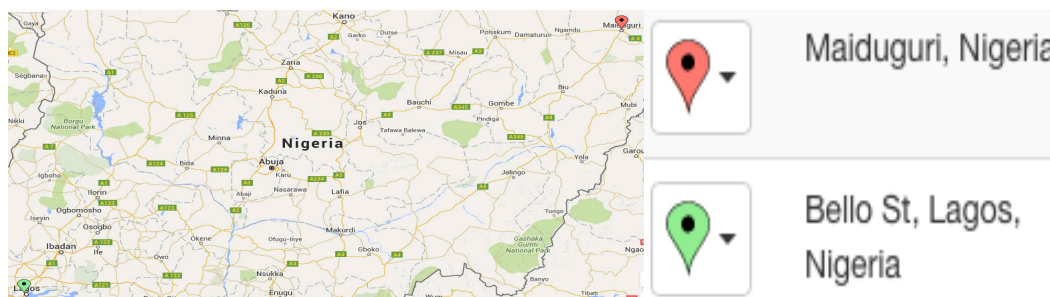
Figure 86. Aframero Limited, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.25 OBM Merchandise Ltd.

OBM Merchandise Ltd. is a company of forest managers, harvesters, and loggers based out of Lagos, Nigeria (Figure 87). They are a trading company, importer, and exporter. OBM Merchandise Ltd. focuses on sawn and structural timber, using African tropical wood available within Nigeria (“Fordaq: The Timber Network”).

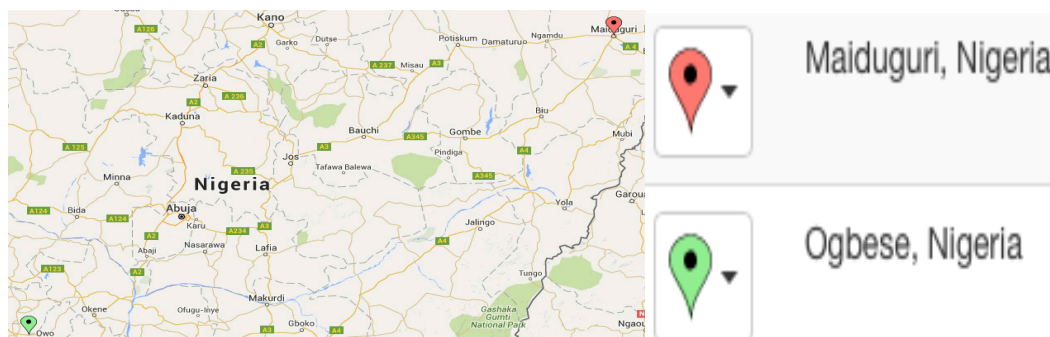
Figure 87. OBM Merchandise Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.26 Thameswood Products

Thameswood Products operates from Ogbese (Figure 88), specializing in supplying sawn timber, logs, and decking to be used for construction purposes. Thameswood products use natural air-drying techniques to minimize the energy used in processing wood products. They also operate a sawmill in Ogbese (“Fordaq: The Timber Network”).

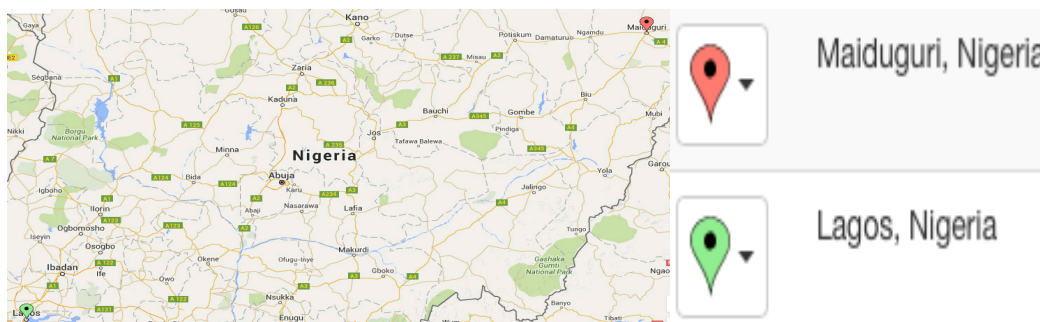
Figure 88. Thameswood Products, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.27 Haran Resources Ltd

Haran Resources Ltd is a Nigeria-based company operating in the Lagos State (Figure 89). The company mainly focuses on sawn and structural timber, using various types of tropical timber found within Nigeria (“Fordaq: The Timber Network”).

Figure 89. Haran Resources Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.28 Akewa Global Services Ltd

Akewa Global Services Ltd is located in Burutu, Nigeria (Figure 90). The company operates tropical wood sawmills from this location in order to meet the needs of its customers (“Fordaq: The Timber Network”).

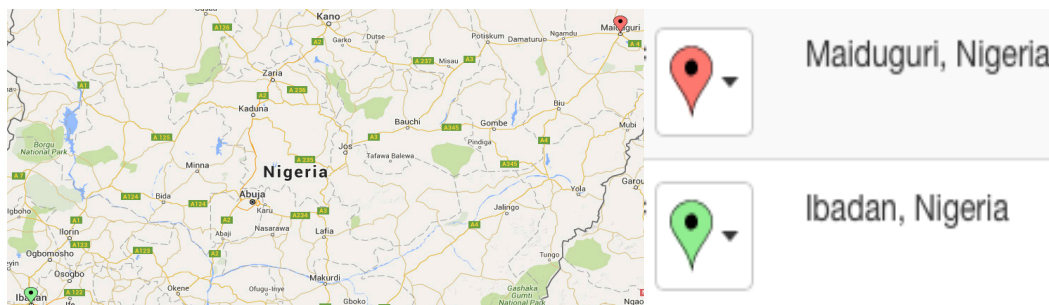
Figure 90. Akewa Global Services Ltd, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.29 Famolin Enterprises

Famolin Enterprises is located in Ibadan, Nigeria (Figure 91). The company operates tropical wood sawmills at this location in order to meet the needs of its customers (“Fordaq: The Timber Network”).

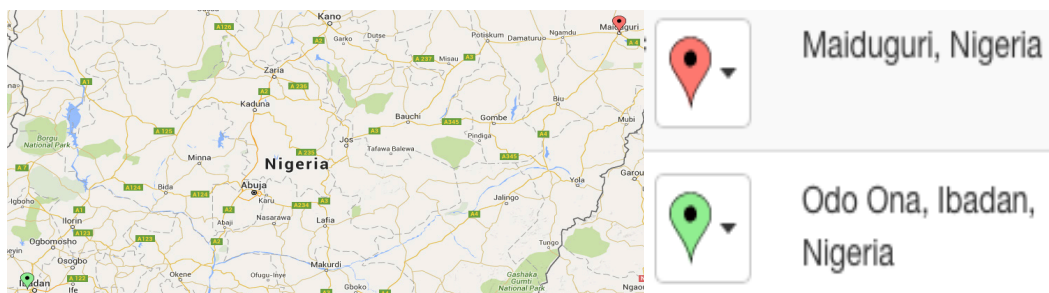
Figure 91. Famolin Enterprises, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.30 Forthnur Company Ltd

Forthnur Company Ltd is a Nigeria-based company operating in the Odo Ona, Ibadan region of the country (Figure 92). The company is mainly a wood trading group; however, they manufacture various other wood products, including plywood and other construction wood pieces (“Fordaq: The Timber Network”).

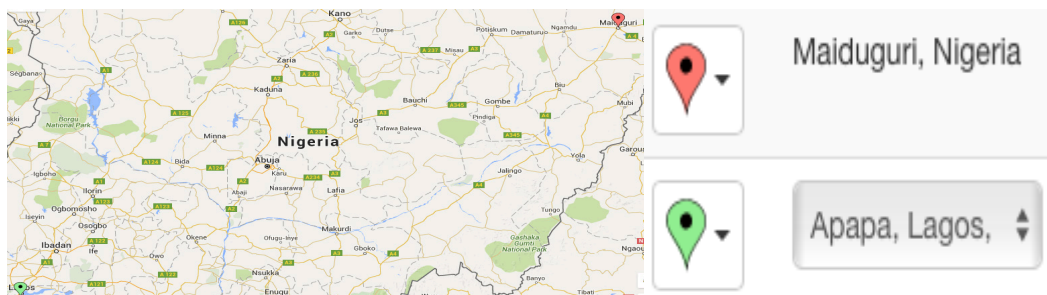
Figure 92. Forthnur Company Ltd location (Google Maps, 2016).



6.1.5.31 Cotoaz Shipping & Logistics Limited

Cotoaz Shipping & Logistics Limited is based in Apapa, Nigeria (Figure 93). The organization is mainly a group of agents and brokers helping import and export wood to and from Nigeria. They specialize in distributing hard, soft, and tropical wood logs. Cotoaz Shipping & Logistics Limited also operates a sawmill that manufactures sawn and structural timber (“Fordaq: The Timber Network”).

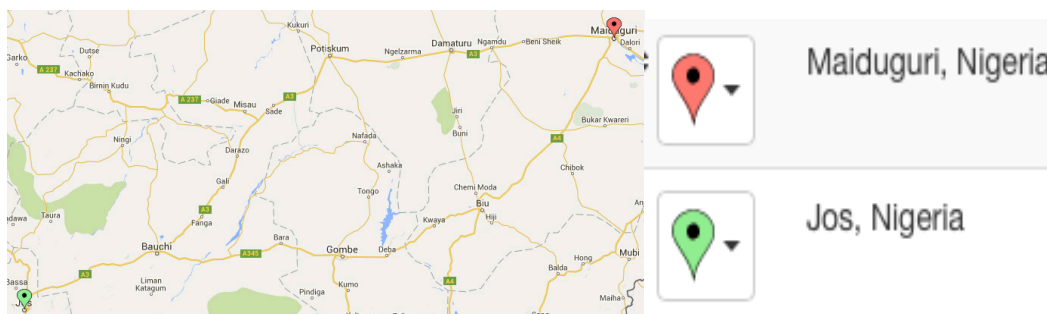
Figure 93. Cotoaz Shipping & Logistics Limited, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.32 Awa Holdings Limited

Awa Holdings Limited operates a group of tropical wood sawmills in the city of Jos, Nigeria (Figure 94). The company is comprised mainly of loggers, who also help produce sawn and structural timber for construction purposes (“Fordaq: The Timber Network”).

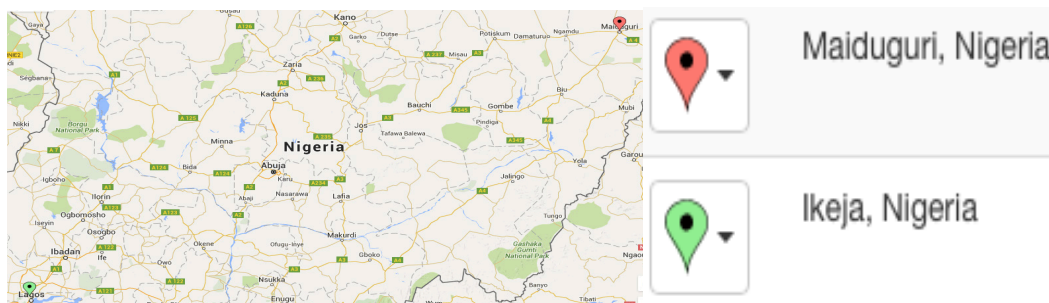
Figure 94. Awa Holdings Limited, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.33 Rosohan System Nigeria Limited

Rosohan System Nigeria Limited is a Nigeria-based company located in the city of Ikeja (Figure 95) that mainly operates as exporters. The company also operates tropical wood sawmills in Ikeja and produces sawn and structural timber (“Fordaq: The Timber Network”).

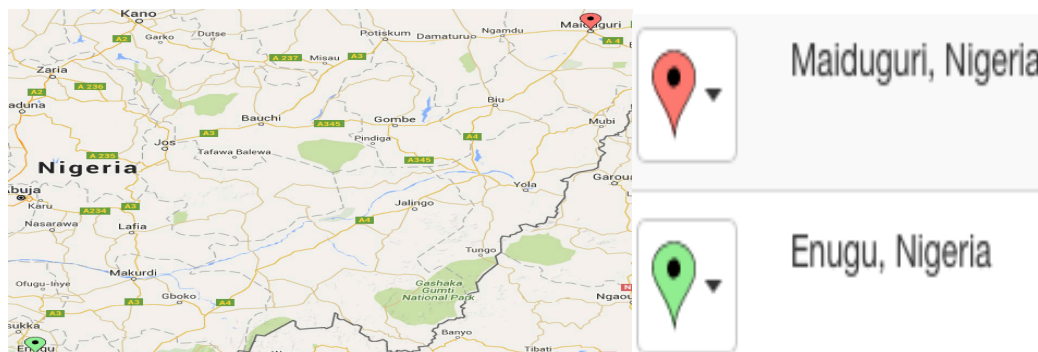
Figure 95. Rosohan System Nigeria Limited, wood location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.1.5.34 Hilicin Limited

Hilicin Limited is a Nigeria-based company operating in the city of Enugu (Figure 96). The company is a manufacturer and producer of structural timber. Hilicin Limited also operates tropical wood sawmills in Enugu (“Fordaq: The Timber Network”).

Figure 96. Hilicin Limited location in Nigeria, relative to Maiduguri (Google Maps, 2016).



6.2 Product

6.2.1 Codes, standards, and methods

The government of Nigeria does not have any set codes or standards for wood production and/or distribution. The Federal Department of Forestry of Nigeria enacted the National Forest Policy in 2008 that aimed to reduce poverty, promote food security, allow for environmental and biodiversity conservation, and establish methods for sustainable production of wood and non-wood products (“Forestry”).

In the United States, most commercial lumber is graded by standardized rules that make purchasing wood more or less uniform in America. Conversely, in Nigeria, there are no standardized grades, but woods are still graded by various companies (Ohagwua 2011).

Many companies follow guidelines provided by the American Wood Council, including the National Design Specifications for Wood Construction and the Wood Frame Construction Manual.

6.2.2 Wood dimensions

In Nigeria, there are various sizes of wood available (Adesogan 2013 and Ohagwua 2011). These include:

- hard wood: 2 x 2, 2 x 3, 2 x 4, 2 x 5, 2 x 6, 3 x 4;
- soft wood: 2 x 4 x 12, 2 x 3 x 12, 1 x 2 x 12;
- resin coated plywood: 18 mm;
- white plywood: 1/8 x 8, 1/4 x 4 x 8, 1/2 x 4 x 8, 3/4 x 4 x 8; and
- veneer plywood: 1/8 x 4 x 8, 3/4 x 48.

6.2.3 Wood types

There are numerous wood types available in Nigeria, irrespective of their location and use. They include: apa, black afara, white afara, afromosia, gmelina, idigbo, canarium, okan, antiaria, lagos mahogany, berlinia, ekki, scented guarea, dry zone mahogany, camwood, pterygote, albizia, alstonia, makore, white sterculia, owewe, dist, okwen, obeche, opepe, african walnut, mansonina, teak, ebony, guarea, iroko, abura, ogea, pterocarpus, erimado, agba, akpu, danta, celtis, and walnut (Ohagwua 2011).

The wood species listed above (with some additions and exclusions) are shown in Figure 97, providing a reference as to whether the wood's purpose is decorative, functional, or structural (Adesogan 2013).

Figure 97. Nigeria wood species characterization (Adesogan 2013).

S/N	Local name	Botanical name	Purpose of use		
			Decorative	Functional	Structural
1	Afara	<i>Terminalia ivorensis</i>	"	"	"
2	Apado	<i>Conluoa grandiflora</i>			"
3	Erun	<i>Erythrophlum suaveolens</i>			"
4	Agbonyin	<i>Piptadeniastrum africanum</i>	"		"
5	Akokokoigbo	<i>Lovoa trichiloides</i>		"	"
6	Teak	<i>Tectona grandis</i>		"	"
7	Omo	<i>Cordia millenii</i>	"	"	"
8	Mahogany	<i>Khaya ivorensis</i>		"	"
9	Agba	<i>Gossweilero tendron balsamiferum</i>			"
10	Arere	<i>Triplochiton acleroxylon</i>			"
11	Apa	<i>Afzelia Africana</i>			"
12	Oro	<i>Nassogoidonia papaverifera</i>			"
13	Araba	<i>Ceiba pentandra</i>			"
14	Ayo	<i>Holoptalea grandis</i>			"
15	Ayin	<i>Anogeissus leicarpus</i>			"
16	Opepe	<i>Nauclea diderrichii</i>		"	"
17	Iroko	<i>Milicea excelsa</i>		"	"

The 17 most commonly used wood types for construction purposes in Nigeria have different conservation statuses. The following seven woods have the following distinction, based on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species:

- Threatened category
 - Vulnerable: *Terminalia ivorensis*, *Lovoa trichiloides*, *Khaya ivorensis*, *Afzelia Africana*, *Nauclea diderrichii*
- Lower-risk categories
 - Near Threatened: *Milicia excelsa*
 - Least Concern: *Nassogoidonia papaverifera*

The wood products industry is a very large one in Nigeria. Various wood products in the country include sawn wood, wood-based panels (plywood, particleboard, and paper), and paperboard (newsprint, and printing and writing paper) (Ohagwua 2011). Currently, the country of Nigeria does not produce fiberboard. The nature of statistics on these products is disorganized and disorderly because there are no systematized methodologies for their regular collection at either the federal, state or local government levels; rather, there are ad-hoc studies that contain various amounts of information, but those studies are very periodic and sporadic (Shmulsky 2002).

Although there are numerous types of wood species available in Nigeria, not all of them are suitable for construction purposes. The three most fre-

quent wood types used for construction purposes in Nigeria are Omo (*Cordia millenii*), Afara (*Terminalia ivorensis*), and Teak (*Tectona grandis*). Conversely, Iroko (*Milicia excelsa*), Opepe (*Nauclea diderrichii*), and Araba (*Ceiba pentandra*) are the least-used wood species in building projects. These results are summarized in Figure 98 (Adesogan 2013).

Figure 98. Frequency of usage of various wood species for construction (Adesogan 2013).

S/N	Local name	Botanical name	Frequency
1	Afara	<i>Terminalia ivorensis</i>	86
2	Apado	<i>Conluoa grandiflora</i>	25
3	Erun	<i>Erythrophium suaveolens</i>	25
4	Agbonyin	<i>Piptadeniastrum africanum</i>	30
5	Akokokoigbo	<i>Lovoa trichiloides</i>	30
6	Teak	<i>Tectona grandis</i>	50
7	Omo	<i>Cordia millenii</i>	90
8	Mahogany	<i>Khaya ivorensis</i>	25
9	Agba	<i>Gossweilero tendron balsamiferum</i>	20
10	Arere	<i>Triplochiton acleroxylon</i>	35
11	Apa	<i>Azalia Africana</i>	38
12	Oro	<i>Nassogoidonia papaverifera</i>	35
13	Araba	<i>Ceiba pentandra</i>	16
14	Ayo	<i>Holoptalea grandis</i>	24
15	Ayin	<i>Anogeissus leicarpus</i>	40
16	Opepe	<i>Nauclea diderrichii</i>	15
17	Iroko	<i>Milicea excelsa</i>	15

6.2.4 Wood characterization

Traditionally in Nigeria, wood products have been used mostly for construction purposes, particularly building construction. Over 80% of the timber and timber products in Nigeria are utilized for different purposes within building construction. The major purposes of timber in building construction are for doors, frames, roofing members, and staircases. Additionally, wood products are used for scaffolding and shuttering during construction. There are various other nonconstruction-related uses of wood in the country, which shows how valuable a commodity it is within the country (Ohagwua 2011). In Nigeria, the general properties of wood have been codified as follows:

- *Density coding*: from 1 for very light to 10 for very heavy.
- *Strength coding*: from S1 for very strong to S7 for weak.
- *Durability coding*: from 1 for extremely durable to 10 for least durable.

- *Permeability coding*: from 1 for very permeable (can be penetrated with wood preservation under pressure treatment) to 7 for least permeable.
- *Color of heartwood*: the appearance has an important effect on the wood's end use.

Various species of wood in Nigeria are characterized by using the above methods of coding its properties, and the results are displayed in Figure 99.

Figure 99. Nigerian woods, characterized by various properties (Ohagwua 2011).

Species	Group	Colour of heartwood	Density code	Strength group	Natural durability code	Use code	Permeability code
Afzelia africana	2	Yellow brown	0	S3	1	1,2,3	
Acacia albida	4	yellow	7	S5	4	2	2
Baillonella toxisperma	3	Red brown	8+	S3	1	1,2,3,6	
Berlina spp	3	Purple brown	10+	S1	1	3,6	
Coula edulis	2	Red brown	9	S1	1	2,3,6	1
Cola gigantean	4	Grey brown	7	S6	4	2,4	
Corynanthe pacyceras	3	Yellow brown	8	S3	3	2,3,6	
Diospyrosmanii	6	Black	0+	S2	4	2,6	3
Damiellaogea	3	Red brown	7	S6	2	2,4	2
Eucalyptus robusta (p)	2	Red brown	9	S3	2	2,3	
Khaya ivorensis	3	Red brown	7	S5	3	1,2	3
Ficus mucoso	5	Yellow	6	S7	4	1,2,4	
Gmelina arborea	4	White	7	S6	3	1,2,4,5	3
Hannoa klameana	5	White	4	S7	4	1,2,4,5	3
Lophira alata	1	Park brain	10	S1	1	3	3
Morus mesozyga	2	Yellow brown	9	S1	3	1,2,3	
Newtonian spp	2	Brown	8	S3	3	1,2,3	
Xylopia rubescens	3	Yellow	8	S3	4	1,2,4	

6.2.5 Wood storing and moisture removal

There are two major methods along the wood sawing process that are used to store processed wood and remove excess moisture in the process. These two methods are air seasoning and kiln seasoning. A typical wood sawing operation is shown in Figure 100.

conditions must be known (i.e., temperature and humidity of the circulating air) (Shmulsky 2002).

6.2.6 Wood data collection constraints

There are many limitations to data collection and forest section statistics in Nigeria, including funding and appropriate infrastructure, public attitude and opinions, and poor communication.

6.2.6.1 Funding and appropriate infrastructure

In Nigeria, funding is the main issue facing forestry data. There is much talk about this issue; however, not much action is being taken. Resources are not distributed properly for the needed data collection. Lastly, the technological equipment needed for proper data collection is not yet available in the region (Ohagwua 2011).

6.2.6.2 Public attitude and opinions

The public of the country perceives the government of Nigeria as very self-serving and calculated. As a result, the public is not in favor of having their concerns heard since it is believed the government misconstrues them. Overall, the poor attitude of the public needs to be improved if various forest sector statistics are to be successfully collected and interpreted (Ohagwua 2011).

6.2.6.3 Poor communication

In conjunction with the lack of funding, poor communication does not allow for information to be shared among various groups of people. If there was greater coordination among the various parties who collect forestry statistics, it is likely that collecting various statistics would be easier. Currently, some effort is being put forth by various organizations within the country; however, there are few results to show for it (Ohagwua 2011).

6.2.7 Bamboo

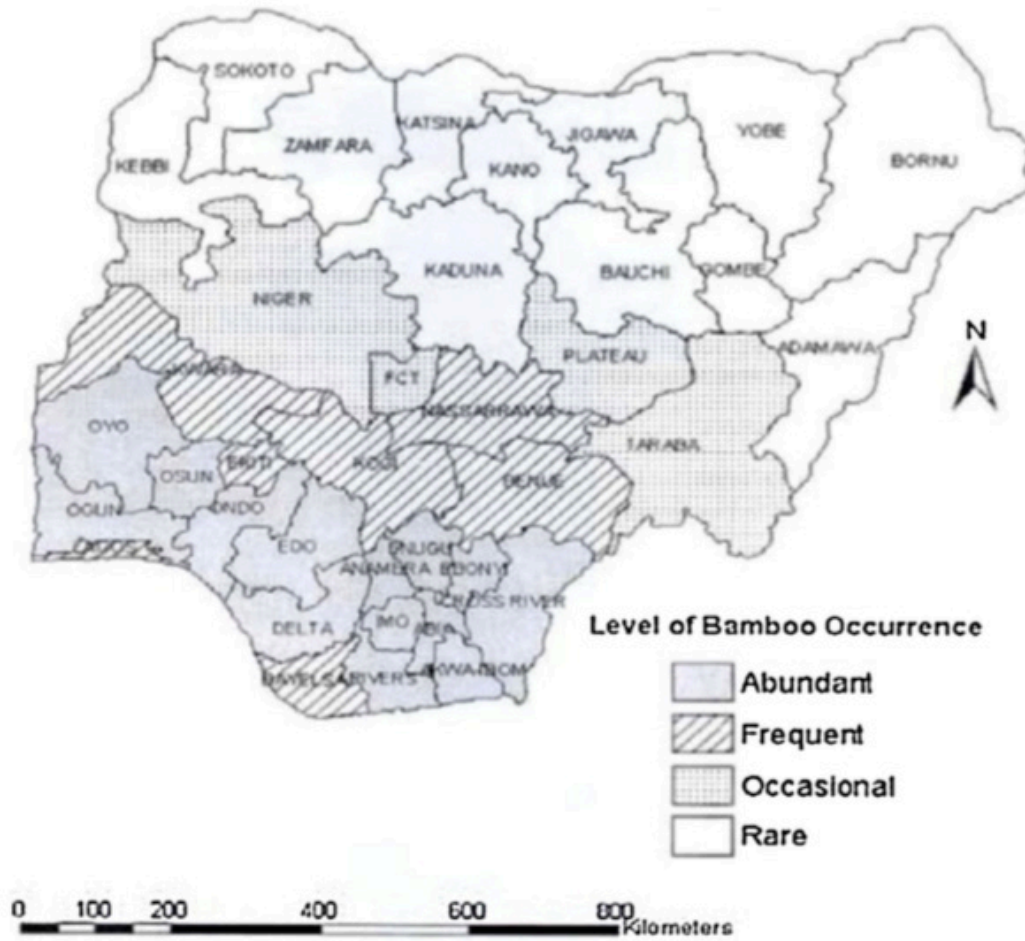
Bamboo is a subfamily of tall tree-like grasses with over 1,400 species, and it is located in tropical, subtropical, and mild temperate regions. It is a fast-growing plant, which grows in clusters and consists of woody ringed stems called culms, which are typically hollow. Bamboo has a wide range of uses, and some of the structural purposes of bamboo include planks for

houses and rafts, scaffoldings, and flooring. Bamboo is more advantageous than wood, as bamboo can be gathered within 3–5 years of planting, whereas wood can only be gathered within 10–30 years (Atanda 2015).

In its current state, Nigeria does not utilize the native bamboo resources properly. The country is highly dependent on wood, which is depleting the wood amounts within the country. As a result, it will become necessary for bamboo to be utilized as a building material to counteract Nigeria's high rate of wood exploitation. There are abundant amounts of bamboo available in Nigeria due to it not being utilized as a construction material. Figure 101 demonstrates the regions in Nigeria where bamboo is available (Atanda 2015).

As a result of the lack of dependence on bamboo, few to none of the companies in the region are distributors of bamboo for construction purposes. Although bamboo is currently not a widely used construction material, a sustainable environment in Nigeria will only be achieved through the added use of bamboo as a construction material. There is a large amount of bamboo available in the country, and it is plausible for the material to be utilized as a construction material in Nigeria. Currently, not much research is being conducted on the bamboo industry in Nigeria, and more is needed to determine the true state of bamboo within the country (Atanda 2015).

Figure 101. Bamboo availability in Nigeria (Atanda 2015).



7 Steel

7.1 Industry

7.1.1 Global scenario

The rise of steel for construction purposes began in the 1850s. Since its emergence as a construction material since that time period, steel has been a vital component of the world's economy. Henry Bessemer's process of forming steel allowed for the cost to become much more affordable, making it a widely used construction material throughout the world. A country's steel industry is the core industry (Nigeria 2014). Such an industry produces a wide variety of products, and consumers input various elements as well. In the 20th century, global steel production grew significantly, from 30.9 million tons at the beginning of the 20th century to 860.9 million tons at the end. Throughout the 20th century, production of crude steel also has increased very rapidly, approaching a production level of 1.8 billion tons per year. Today, it is difficult to imagine a world without steel (Darity 2008).

7.1.2 Background

Although Nigeria is a developing country, there is a steel industry present in the country. Initial planning for a steel industry within Nigeria began around 1958. Under the Federal Ministry of Industries, various companies were brought in to determine the feasibility of operating large-scale steel plants. The Nigerian Steel Development Authority (NSDA) was created in 1971 with the goal of heading the efforts to actualize a steel plant, which was operational by 1983 (Ajayi 2014). Nigeria has yet to efficiently start exploiting the steel industry in terms of revenue within the country. For example, Nigeria's steel consumption per capita is only 10 kg, compared to the world average of 150 kg (Nigeria 2014). Despite this low consumption and based on numerous studies, there is the capability for the steel industry to succeed in Nigeria (Obikwelu 2012).

7.1.3 Regionalism and competitiveness

The steel industry in Nigeria is not one that is highly competitive yet (Obikwelu 2012). This is due to the lack of infrastructure needed for companies to compete against each other. Despite this, the 2014 Nigeria Industrial Revolution Plan (NIRP) aims to create a highly competitive steel industry within the country. Currently the country of Nigeria specializes in the

production of the raw materials needed for steel production, and the country exports those materials. The NIRP states that “history shows that no country has ever become rich by exporting raw materials without also having an industrial sector, and in modern terms an advanced services sector. The more a country specializes in the production of raw materials only, the poorer it becomes.” Thus, part of the plan is to create a highly regional and competitive market (Nigeria 2014).

Since the creation of Nigeria’s steel industry in the late 1950s, the sector has failed to adapt as necessary, leading it to lack the needed economic growth and development. Overall, the industry does not have the basic infrastructure in place for steel and iron. Along with this, there are not enough skilled workers to allow for true competitiveness in the industry. Consequently, the sector is unable to attract the necessary investment for economic growth and remains a small player in the economy. Despite this, Nigerians are optimistic of their steel industry’s future (Nigeria 2014).

7.1.4 Steel producers – Nigeria

As a result of the NIRP, the country’s steel industry has grown tremendously compared to the mid-2000s. Based on various news reports, more than 21 functional steel mills and 22 steel companies have been established as a result of the growing Nigerian steel industry (Aluko 2015).

7.1.4.1 Various steel producers in Nigeria

The following companies are newly created steel companies in Nigeria that only have available the information provided in Table 5. The various locations of these mills are depicted in Figure 102 (integrated mills), Figure 103 (rolling mills – 1), Figure 104 (rolling mills – 2), and Figure 105 (mini mills).

Table 5. Various steel companies in Nigeria (Ohimain 2014).

Type of Mill	Company	Location	Rolling Capacity (tons per annum)	Products
Integrated Mill	Ajaokuta Steel Co. Ltd.	Ajaokuta	540,000	Bars, rods, light sections
Integrated Mill	Delta Steel Co.	Aladja-Ovwian	320,000	Bars, rods, sections
Rolling Mill	Alliance Steel Co.	Ibadan	20,000	Bars
Rolling Mill	Alliance Steel Co.	Onitsha	20,000	Bars

Type of Mill	Company	Location	Rolling Capacity (tons per annum)	Products
Rolling Mill	Asiastic Manarin Ind.	Ikeja	60,000	Bars, sections
Rolling Mill	Jos Steel Rolling Company	Jos	210,000	Bars, rods
Rolling Mill	Kastina Steel Rolling Co.	Kastina	210,000	Bars, rods
Rolling Mill	Kwara Commercial, Metal and Chemical Industries	Ilorin	40,000	Bars
Rolling Mill	Mayor Eng. Co.	Ikorodu	220,000	Bars, sections
Rolling Mill	Metcombe Steel Co.	Owerri	10,000	Bars, sections
Rolling Mill	Dangote Steel (formerly Oshogbo Steel Co.)	Oshogbo	400,000	Bars, rods
Rolling Mill	Qua Steel Products	Eket	600,000	Bars, sections
Rolling Mill	Selsametal	Otta	100,000	Bars
Rolling Mill	Union Steel Co.	Ilorin	20,000	Bars
Rolling Mill	Baoyao Futurelex	Abuja	20,000	Bars
Mini Mill	Federated Steel Industry	Otta	140,000	Bars, sections
Mini Mill	General Steel Mill	Asaba	50,000	Bars
Mini Mill	Universal Steel Co.	Ikeja	80,000	Bars, sections
Mini Mill	Nigerian Spanish Eng. Co.	Kano	100,000	Bars
Mini Mill	Nigersteel Co.	Enugu	40,000	Bars, sections
Mini Mill	Continental Iron & Steel Co.	Ikeja	150,000	Bars, sections
Mini Mill	Kew Metal Industries	Ikorodu	20,000	Bars, sections

Figure 102. Integrated mill locations in Nigeria (Google Maps, 2016).

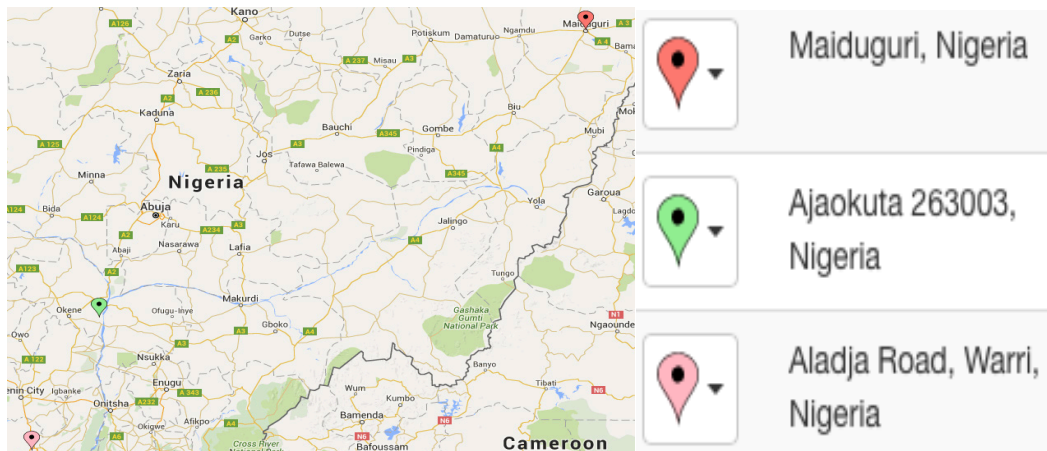


Figure 103. Rolling mill locations - 1 in Nigeria (Google Maps, 2016).



Figure 104. Rolling mill locations - 2 in Nigeria (Google Maps, 2016).

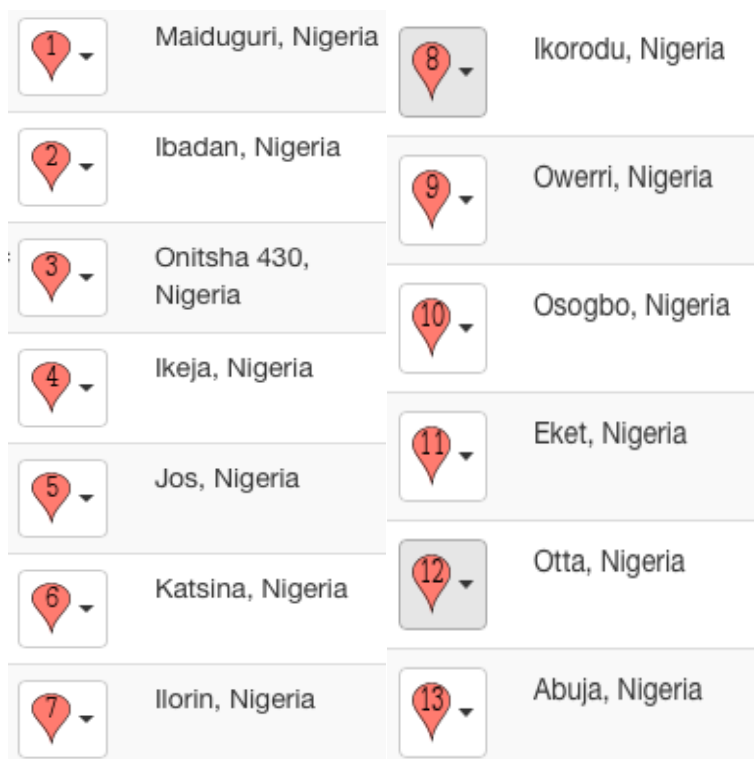
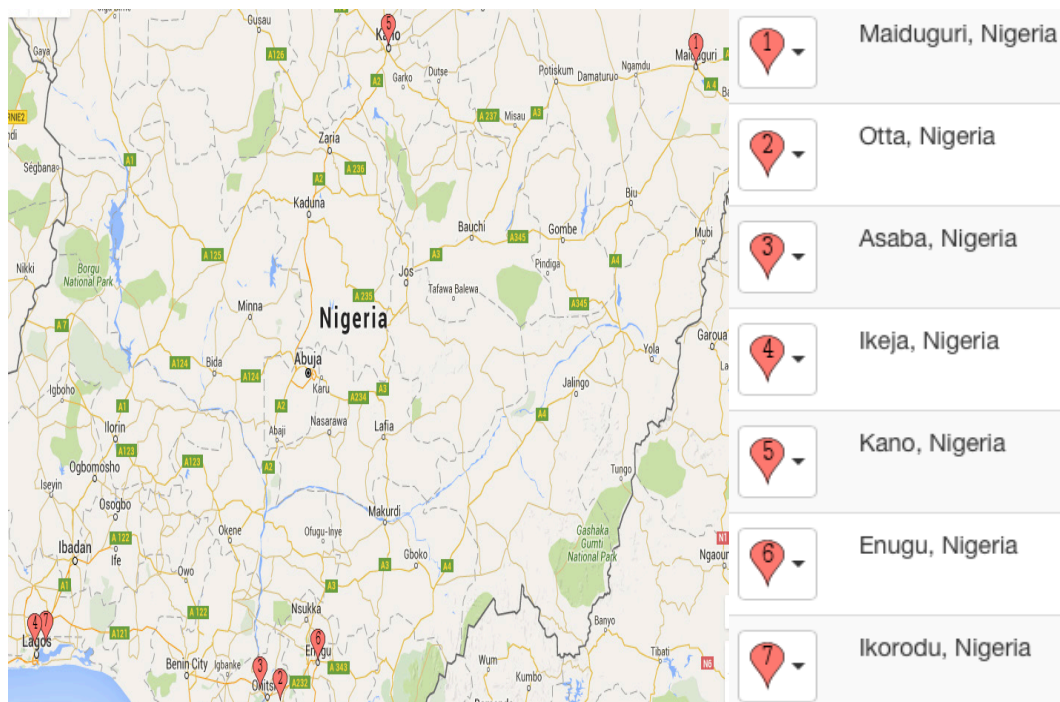


Figure 105. Mini mill locations in Nigeria (Google Maps, 2016).



7.1.4.2 Ajaokuta Steel Company Limited

Ajaokuta Steel Company (from Table 5) is located in Ajaokuta, Nigeria. The company has an integrated steel plant on 800 ha of land. For steel production, the company uses blast furnace—basic oxygen furnace technology. The company produces 1.3 million MTPA of steel, with plans to increase its capacity to 2.6 MTPA in the near future and to 5.2 MTPA after that. The company produces wire rod (5.5–12 mm) and rebar (8–30 mm). Ajaokuta Steel Company also has a billet mill (795,000 tons per annum [TPA]), wire rod mill (130,000 TPA), light section mill (400,000 TPA), and medium section and structural mills (560,000 TPA). The company also has a thermal power plant on site that can produce a total of 110 mega Watt (mW) from 2 generators of 55 mW each. The type of steel the company produces from each of the mills is further expanded below (“Ajaokuta Steel”).

- Billet Mill
 - 100 x 100 mm
- Wire Rod Mill
 - Wire rods of size between 5.5 mm to 12.5 mm
 - Rebars of size between 6.0 mm to 12 mm
- Light Section Mill
 - Plain and rebar: 10–30 mm
 - Squares: 10–30 mm
 - Hexagons: 10–14 mm and 20–26 mm
 - Angles: 25 x 25 to 50 x 50 mm in thickness, between 3 – 6 mm
 - Channels: 30–45 mm
 - T-sections: 30–60 mm
 - Strips: 6–12 mm (tall) x 12–70 mm (wide)
- Medium Section and Structural Mill
 - I beams: 80–300 mm
 - Channels: 80–300 mm
 - Equal angles: 70 x 70 mm–130 x 130 mm
 - Unequal angles: 50 x 80 mm and 100 x 160 mm
 - Flats: 70–150 mm (width) x 10–20 mm (thickness)

7.1.4.3 Dangote Steel

Dangote Steel acquired the assets of Oshogbo Steel Rolling Mills (from Table 5). The company has upgraded the production capacity from 210,000 to 400,000 TPA. Currently the company operates as a rolling mill and produces steel bars and rods. These products include mild steel (MS) and high

tensile (HT) ribbed bars from billets, plain bars, and rebar (“Dangote Steel”).

7.1.4.4 TOP Steel Nigeria Limited

TOP Steel Nigeria Limited (TSNL) is a 100% wholly owned subsidiary of Top Metals Limited, with its manufacturing unit located at Lagos, Nigeria. The company has an integrated steel plant with rolling capacity of 219,000 TPA. Also, TSNL operates the following facilities: steel melting shop, continuous casting machine, high-speed rolling mill, 132/33 kV substation, oxygen / nitrogen plant, argon oxygen decarburization (AOD) plant (“TOP Steel”).

7.1.4.5 Nigeria Gas and Steel Ltd

Nigeria Gas and Steel Ltd. is located in the Oregun Industrial Estate in Ikeja, Lagos, Nigeria. Currently, the company operates at a capacity of 30,000 TPA, with an installed capacity of 72,000 TPA. The products the company specializes in include steel tubes and hollow structural sections (HSS), which are available in round, square, and rectangular sections, with a broad range of sizes and thicknesses (“Nigeria Gas and Steel Ltd”).

7.2 Product

7.2.1 Codes, standards, and methods

In past years, there has not been a great deal of information regarding the codes, standards, and methods for steel production and distribution (Ajayi 2014). This resulted from a very weak steel industry and very few companies that were manufacturing steel products in the country. Currently, with the help of the NIRP, the country is trying to create a prosperous steel industry to industrialize the country. As a result, the Nigerian government plans to enforce international steel production measurement standards. For example, the government of Nigeria is currently assisting the country’s Ministry of Mines to help various mineral deposits meet Joint Ore Reserves Committee (JORC) standards (NIRP 2014). The JORC codes are the Australasian professional code of practice that sets minimum standards for public reporting of exploration results, mineral resources, and ore reserves (“JORC”). There are various Nigeria codes in place for steel production and testing; however, it has been determined that many concerns of these codes are being cut in order to save on costs. These codes include: “Methods of Testing of Steel” (NIS 199: 1984), “Standards for Iron and

Steel” (NIS 499: 2004), “Standards on Steel Bars for Reinforcement of Concrete” (NIS 117: 1983), and “Specification for Structural Steel” (NIS 197: 1984).

As of 8 March 2016, various Nigeria news outlets, including “This Day Live,” began reporting that the SON has stated it plans to introduce stricter measures on erring steel and iron producers who fail to meet the minimum requirement of the NIS; however, these measures have yet to be determined (“SON to Enforce” 2016).

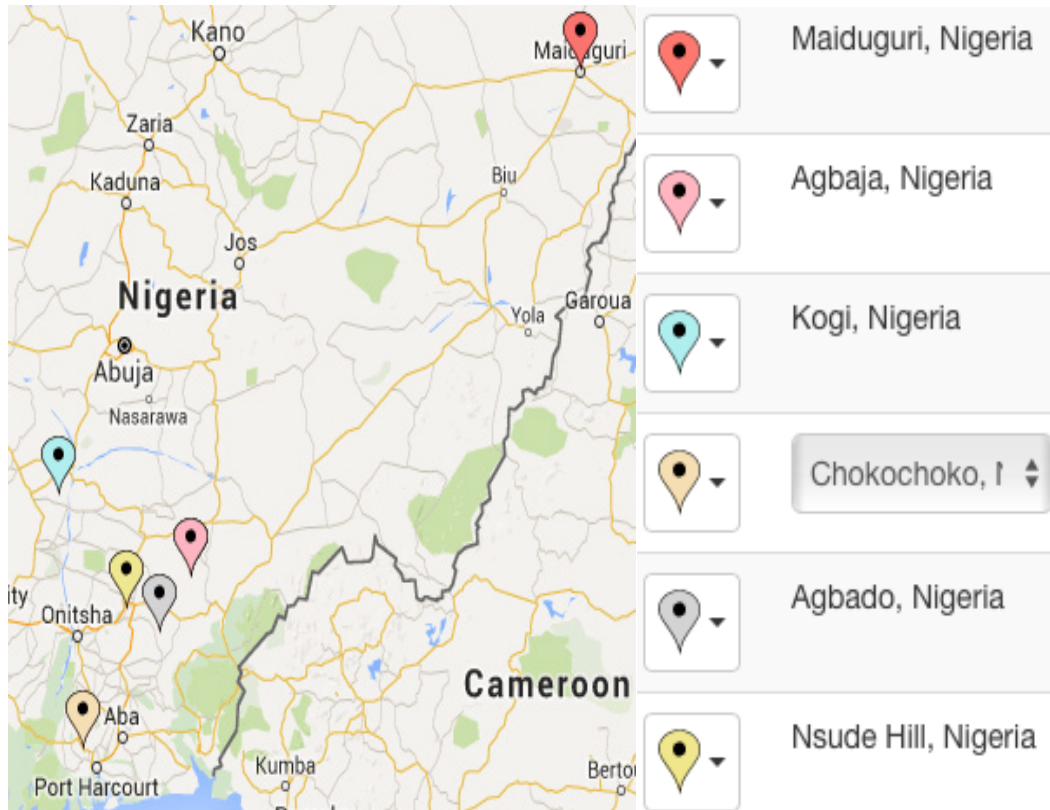
7.2.2 Ore reserves

Nigeria has almost 3.3 billion tons of iron ores located in six fields throughout the country: Agbaja, Itakpe, Ajabanoko, Chokochoko, Agbade-Okudu, and Nsude Hills. Along with these proven ore deposits, there are other deposits currently under investigation. The iron content of the proven ore reserves is in the range of 36%–54%. Of the six Nigerian iron ore fields, thus far only Itakpe (with an iron content of 36%) has been developed (Ohimain 2014). The Nigeria National Iron Ore Mining Company Ltd, which is located at the Itakpe ore deposit, was designed to supply iron ore to both of the integrated mills in Nigeria, Ajaokuta Steel Company and Delta Steel Company. In turn, the Nigeria National Iron Ore Mining Company hopes to supply billets to rolling mills in the country as well (Nigeria 2014). Table 6 provides information about the ore deposits within Nigeria. The various locations are depicted in Figure 106.

Table 6. Iron ore deposits in Nigeria (Ohimain 2014).

Location	Iron Content (%)	Reserves (million tons)
Agbaja	45–54	2204.6
Itakpe	36	220.5
Ajabanoko (Kogi State)	35.61	68.9
Chokochoko	37.43	77.2
Agbade-Okudu	37.43	77.2
Nsude Hills	37.43	66.1
TOTAL		2714.4

Figure 106. Nigerian iron ore deposit locations (Google Maps, 2016).



7.2.3 Steel types

Based on the NIRP, there are various products included in the scope of production for the country. These products include: blooms, billets, sheet metal, plates, bars, rods, wire, and structural frames. Along with this, the NIRP scope aims to focus the country on smelting, hot rolled products, cold rolled products, and local distribution (Nigeria 2014).

7.2.4 Mill types

There are three different types of mills in Nigeria: integrated, rolling, and mini mills.

- **Integrated Mills:** These mills have all the functions for primary steel production including iron making, steelmaking, casting, roughing/billet rolling, and product rolling. The principal raw materials for an integrated mill are iron ore, limestone, and coal (or coke).
- **Rolling Mills:** Rolling mills are metal-forming locations that process metal stock. This metal stock is passed through one or more pairs of rolls to reduce the thickness and to make the thickness uniform. Most

steel mills have rolling mill divisions that convert the semi-finished casting products into finished products.

- Mini Mills: A mini mill is traditionally a secondary steel producer that obtains most of its iron from scrap steel that is recycled from used automobiles and equipment or from byproducts of manufacturing.

7.2.5 Steel constraints

There are many factors that have led to the current state of the steel industry in Nigeria, including lack of will, unnecessary linkages, and improper feasibility work (Obikwelu 2012).

7.2.5.1 Lack of will

In Nigeria, there is currently a lack of will to thrive as a major player in the worldwide steel industry. Because not much is known about steel processing or manufacturing in the country, companies and individuals are reluctant to join the steel industry (Obikwelu 2012).

7.2.5.2 Unnecessary linkages

There are various unnecessary linkages for nontechnical reasons that cause poor operation of the steel plants in Nigeria. Various companies believe that they must manufacture all things steel in order to be competitive, when in reality, it would be better for some companies to focus on one type of product (Obikwelu 2012).

7.2.5.3 Improper feasibility work

Many Nigerians believe that the initial feasibility work was improperly conducted. One of the main feasibility studies was conducted with the intent to import over 70% of the raw materials needed for steel production. Some Nigerians now believe that this intent was improperly recommended, as the country is struggling with importing the necessary materials (Obikwelu 2012).

7.2.6 Steel goals of Nigerian Industrial Revolution Plan

There are various goals that are laid out in the NIRP for how Nigeria will be able to create a thriving steel industry. These goals include: investment promotion downstream (with gradual backward integration upstream),

prove up mineral resources, reduce exportation of scrap metal, and create clusters of steel companies.

7.2.6.1 Investment promotion downstream

Nigeria plans to promote very strategic investments in large-scale downstream rolling mills (cold- and hot-rolled) that are near known mineral deposits and/or near port areas, in order to make steel processing and distribution more viable. Also, the NIRP plans to assist the key players who have a large, installed, cold-rolling mill capacity integrate backwards to a hot-rolled process. Once this integration is complete, the final phase is to integrate the smelting process (Nigeria 2014).

7.2.6.2 Prove up mineral resources

The government of Nigeria plans to work with the country's Ministry of Mines to bring the key mineral deposits for steel production up to international measurement standards (JORC standards). Lastly, the NIRP hopes to engage existing downstream steel companies with investment packages that link proven deposits to their existing operations to help meet international standards (Nigeria 2014).

7.2.6.3 Reduce exports of scrap metal

The third goal of the NIRP for increasing the viability of the steel industry is focusing on reducing exportation of scrap metal. The NIRP plans to review various methods the government currently uses for enforcing restrictions on scrap metal and steel exportation. The Nigerian government plans to integrate various Nigerian ministries to ensure that restrictions are properly implemented (Nigeria 2014).

7.2.6.4 Create steel clusters

As a medium- to long-term goal, the NIRP aims to create various clusters of steel companies throughout the country. The NIRP plans to centralize new players in the steel industry around specific industrial cities (clusters and zones) in each of Nigeria's geopolitical zones. The NIRP hopes to create at least eight of these type of industrial cities. By doing so, the NIRP hopes to ensure that infrastructure will be shared, to lower operating costs. Since the steel industry is energy-intensive, the NIRP also plans to focus on developing gas infrastructure around these industrial cities, to meet the industry's energy demands (Nigeria 2014).

8 Masonry units: block and brick

8.1 Industry

8.1.1 Global scenario

Brick is one of the oldest building materials in the world and continues to be the most popular and leading construction material in developing regions because of being cheap, along with other properties. Bricks are also chosen for their attractive appearance and superior properties such as: high compressive strength and durability, excellent fire and weather resistance, good thermal and sound insulation, and being easy to handle and work with (Jock et al. 2013).

Concrete blocks are becoming increasingly more popular throughout the world, including in developing nations, and the production of these construction materials is becoming the backbone of infrastructural development in almost every country worldwide. Concrete is one of the most widely used construction materials in the world, making the production of concrete blocks easier. The raw materials used to prepare concrete blocks include cement and aggregates. Aggregates are usually cheaper than cement, and aggregates constitute over 70% the volume of concrete (Apebo 2013).

8.1.2 Background

A survey done on raw materials research and development by the Council of Nigeria looked at the types of block/brick available for construction purposes within Nigeria. These construction materials include: cement/lime stabilized bricks/blocks, sundried soil (adobe) blocks, burnt clay bricks/blocks, cast in-situ walls, rice husk ash (RHA), mud and straw, and lime and stonecrete blocks (Sholanke 2015).

A brick is typically used to denote any rectangular unit that is laid in mortar. There are two main types of brick-like products used in the construction industry: clay bricks and concrete blocks (the latter also known as concrete masonry unit [CMU]). Clay bricks are a building material used to make walls and other masonry construction elements. Conversely, concrete blocks are brick-like; however, blocks are larger in nature.

Clay bricks are those that are fired upon formation to create the brick. These bricks are typically red or maroon in color due to the materials used

to make them. These bricks are one of the strongest and longest-lasting building materials. Clay bricks have been used longer than other brick types. There are also air-dried bricks (mudbricks) used for construction purposes; however, these are typically weaker than fired bricks.

Concrete blocks are grey in color as a result of the concrete used in their manufacture. These products mainly began being used in the construction industry in the early to mid-1900s. Concrete blocks are typically used for walls (foundation, basement, partition, exterior, and cavity). This construction material is durable, easy to install, fireproof, inexpensive, lightweight, low maintenance, and can be ornamented.¹⁷ Another type of concrete block is yellow-white in color and known as sandcrete block, which is comprised of natural sand, water, and binder. In Nigeria, 95% of wall materials for building construction are made of sandcrete blocks (Jock et al. 2013).

8.1.3 Regionalism and competitiveness

As a result of the high level of poverty among West African countries such as Nigeria, blocks and bricks are one of the most widely used and accepted construction materials in the country. These materials are used widely across the country in order to minimize the cost of construction works (Sholanke 2015). Along with this high rate of use, the block and brick manufacturing and distribution industry is one of the largest production sectors of the construction industry in Nigeria (Jock et al. 2013).

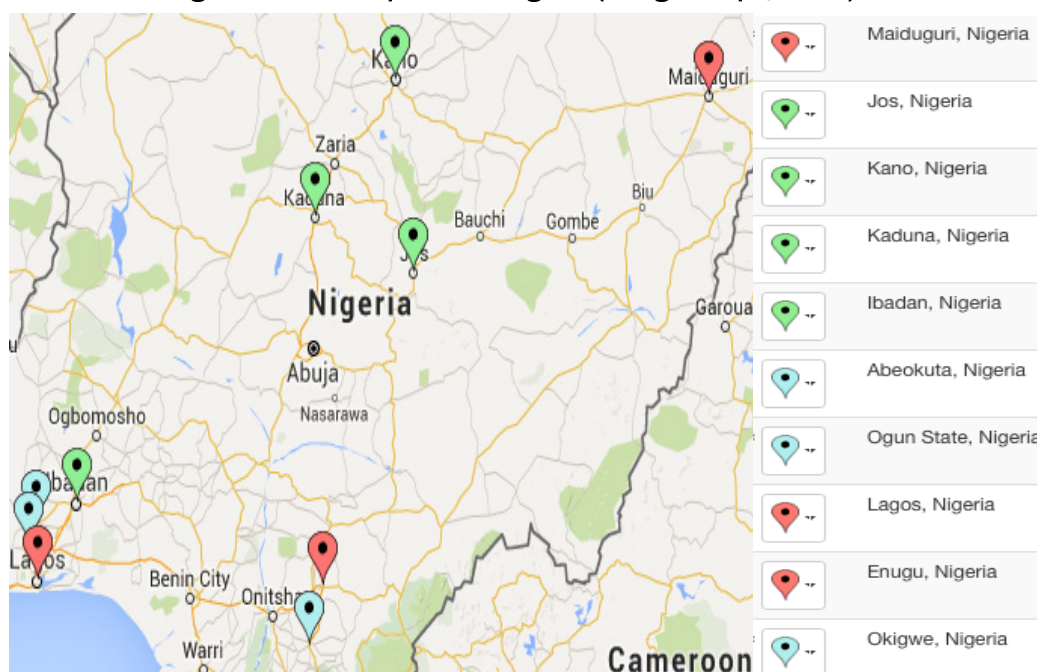
Practically every local government area (LGA) in Nigeria has one or more small-or large-scale block/brick production factories, because block production is a profitable business if properly managed. At present, numerous block molding firms have started operations within Nigeria to meet the requirements of construction and infrastructural development, because there are no set guidelines for who is qualified to produce blocks for use in Nigeria (Sholanke 2015).

¹⁷ Britannica Academia, Online ed., s.v., "Brick and tile." Accessed 15 March 2016. <https://www.britannica.com/technology/brick-building-material>.

8.1.4 Brick producers – Nigeria

There are various large-scale brick producers in Nigeria. In general, these producers are located around major clay deposits. There are roughly 10 brick-producing areas in the country (Figure 107) (Otoko 2014).

Figure 107. Brick plants in Nigeria (Google Maps, 2016).¹⁸



The clay brick site locations are generally located around the principal clay deposits in Nigeria, which are listed in Table 7.

Table 7. Principal clay deposits in Nigeria (Otoko 2014).

State	Location of Principal Deposits
Benue and Plateau State	Jos, Ropp and Markurdi areas
Imo, Ebonyi, Enugu and Anambra States	Enugu, Ezi Akwu, Ekwe and Agbahara
Kano State	Kano and Rimi areas
Lagos State	Epe, Ikorodu and Badagry areas
Edo and Delta States	Benin city, Sapele and Ugheli areas
Borno State	Maiduguri and Gombe areas
Sokoto State	Sokoto and Kuban village

¹⁸ Each point represents a brick plant operated by: red – Nigerian Mining Cooperation and private entrepreneurs, green – Nigerian Mining Cooperation, and blue – private entrepreneurs.

State	Location of Principal Deposits
Rivers State	Port Harcourt and Andoni areas
Akwa Ibom and Cross River State	Ekpene Obom area
Ogun State	Abeokuta and Ijebu-Ode areas

8.1.5 Block producers – Nigeria

Block producers in Nigeria can be categorized into private and commercial producers (Sholanke 2015).

Private-Use Producers. Private-use producers are those who produce blocks strictly for private use. Some clients and contractors engage in the business of making blocks for private use on their buildings and infra-structural projects. These clients and building contractors employ block makers and provide them with materials and all other necessary logistics to produce the block requirement of their projects for the purpose of ensuring quality and reducing cost. Such blocks are usually produced on the project site. On small projects the manual method of mixing and molding are predominately used while on large-scale projects mixers and block molding machines are employed (Sholanke 2015).

Commercial Producers. Commercial producers include both small- and large-scale producers. Small-scale producers use manual methods of mixing and molding, while large-scale producers employ mixers and block molding machines. Commercial block production customers are people who could not produce block on their own (Sholanke 2015).

Because the block molding industry is one of the largest production sectors of the construction industry in Nigeria, it is difficult to pinpoint exact locations of either private-use or commercial producers. Many of these locations are scattered throughout the country. Due to the lucrative nature of block production, virtually every LGA has one or more small- or large-scale block production factories (Sholanke 2015).

8.2 Product

8.2.1 Codes, standards, and methods

As the following information will depict, the government has enacted adequate laws and guidelines to standardize and regulate production of blocks and brick to ensure quality; however, there are little or no practical

measures in place to ensure that block manufacturers adhere to such guidelines. The responsibility of making sure that blocks to be used for construction purposes in Nigeria are of good quality falls on the relevant supervisory professionals on the respective projects (Sholanke 2015).

According to the first edition of the National Building Code of the Federal Republic of Nigeria (Nigeria 2006), there are the following stipulations for sandcrete block manufacturing in country:

- **Sandcrete Blocks**: a composite material made up of cement, sharp sand, and water.
 - Blocks shall be molded for sandcrete using metal (wood) molds of:
 - * 450 mm x 225 mm x 150 mm
 - * 450 mm x 225 mm x 225 mm
 - * 450 mm x 225 mm x 100 mm
 - Blocks are usually joined by mortar, which is a rich mix of sandcrete.
- **Aggregate**: includes both coarse and fine aggregate, from natural sources, blast furnace slag, crushed clay and furnace clinker.
- **Sand**: shall be of approved clean, sharp, fresh water or pit sand, free from clay, loam, dirt, organic or saline water of any description and shall mainly pass 4.75 mm test sieve. If lagoon sand is used this must be properly washed to the approval of the supervisor.
- **Mix Proportion**: Mix used for blocks shall not be richer than 1 part by volume of cement to 6 parts of fine aggregate (sand) except that the proportion of cement to mix-aggregate may be reduced to 1:4 $\frac{1}{2}$ (Where the thickness of the web of the block is one 25 mm or less).
- **Strength Requirements**: Sandcrete blocks shall possess resistance to crushing as stated below and the 28-day compressive strength for a load-bearing wall of two or three story building shall not be less than: average strength of 6 blocks, lowest strength of individual block 2.00 N/mm² (300 psi), 1.75 N/mm² (250 psi).
- **Molding**: The 28-day compressive strength of a sandcrete block for load bearing wall of two or three story buildings shall not be less than the values given above and shall comply with the existing NIS specification for sandcrete blocks.
- **Compaction**: Two methods to be applied, depending on the availability of materials (tools), are by:
 - approval (standard) machine compaction, or
 - metal mold (hand) compaction.

- Production/Processing: The sandcrete block shall be cast using an appropriate machine with cement/sand ratio of 1:6 measured by volume. Where hand mixing is carried out, the materials shall be mixed until an even color and consistency throughout is attained. The measure shall be further mixed and water added through a fire hose in such sufficient quantity as to secure adhesion. It shall then be well rammed into molds and smoothed off with a steel face tool
- Curing: After removal from machine, the blocks shall be left on pallets under cover in separate rolls, one block high, with a space between each block for at least 24 hours, and kept wet by weathering through a fire watering hose. The blocks may then be removed from the pallets, and the blocks may be stacked (during which time the blocks shall be kept wet). The blocks may be stacked not more than 5 blocks high under cover at least seven (7) days before use after the previous period.
- Physical Requirement: Special sizes and shapes of blocks and bricks—11.25 mm (i.e., 4 1/2 in.) thick or less shall be solid with grove and tongued joints. Blocks of thickness greater than 11.25 mm (i.e., 4 1/2 in.) shall be hollow or used above damp-proof course. Hollow blocks shall be more than 50 mm thick. Hollow blocks shall be used only where vertical steel reinforcement is to be fixed.

As previously mentioned, there are no set guidelines for who is qualified to produce blocks/bricks for use in Nigeria. The quality of blocks and bricks in the country is inconsistent as a result of the different production techniques utilized by various producers. Along with this production inconsistency, the properties of the constituent materials used also can significantly alter the structural capacity of a particular block/brick. In Nigeria, there is not a specific standard for sizes and weights of block/brick materials. As such, these materials are of sizes and weights that can be easily handled by bricklayers, with the facing surface layer than that of a brick but conveniently dimensioned (Sholanke 2015).

In many parts of Nigeria, the major cost components of the most common buildings are the sandcrete hollow blocks. These blocks are usually manufactured with the use of a vibrating machine. Lastly, in Nigeria, bricks are an alternative to sandcrete blocks; however, the clay suitable for making high-strength bricks is not available everywhere in Nigeria, and the clay bricks produced and presently used for construction in Nigeria are not uniform in quality (Sholanke 2015).

In order to improve the overall quality of blocks and bricks being used for construction purposes in Nigeria, the citizens of Nigeria believe that the government should begin to look more into block production practices in order to enhance quality, with the overall aim of reducing building collapse. Also, Nigerians believe that quality controls should be introduced to assist block producers to produce strong and durable blocks at minimum cost (Jock et al 2013). It is the general belief in Nigeria that government regulatory agencies need to take other necessary measures of ensuring quality such as requiring compressive tests on blocks from time to time as a mandatory quality control measure needed to secure a quarterly government certification that will enable them to continue in operation. Lastly, block manufacturing should not be left to people only in it for the business and who have no knowledge of the necessary block and brick characteristics (Sholanke 2015).

8.2.2 Operation

Brick-working facilities in Nigeria commonly operate in close proximity to nearby clay quarries in order to satisfy their needs for raw materials, and most facilities and quarries are owned and operated by the same company. The brick market in the country has been presented with significant changes as a result of the introduction of concrete blocks, as the blocks have begun to replace clay bricks for construction purposes (Apebo 2013). As a result of this change, the market has shifted, and clay bricks are now being used for aesthetic purposes in the country. Over the past seven years and into the present, over 90% of the demand and production of clay bricks are for aesthetic purposes (Jock et al. 2013).

8.2.3 Block and brick constraints

Many people in Nigeria accept the use of sandcrete blocks as a substitute to actual concrete blocks made with OPC. This acceptance results from the high cost of cement, which is used as a binder in actual concrete blocks. As such, producers of block in Nigeria produce blocks with low OPC content so that it is affordable to clients and helps reduce the overall cost of construction. The use of sandcrete blocks does not come without drawbacks, however. Improper use of sandcrete blocks in the country leads to microcracks of the blocks after construction. This cracking results in an increased amount of structural damage to a building, which has turned out to be problematic to the construction industry in Nigeria (Jock et al. 2013).

There are several other factors that are responsible for the deterioration and eventual failure of structures being built with block and brick in Nigeria. One of these problems is the use of poor quality blocks and bricks for construction purposes. Thus, it is important to ensure that the production of this major masonry unit is not only standardized but also regulated and adequately monitored to ensure quality (Sholanke 2015).

9 Construction Material Database

9.1 Purpose

A database of construction materials is a collection of information that identifies a site, the geographic location, and the characteristics of that site. The information on materials in the production of aggregate, cement, concrete, brick, steel, and lumber for Nigeria were implemented into a geodatabase to more easily picture, analyze, and comprehend patterns and relationships (Tables A7–A14 in this report’s appendix).

9.2 Categories

Each entry within the database is given 19 fields, which may be of a variable type string or number. Contents of the fields are described below.

9.2.1 Site identification

- *Company*: additional information about the name of the company that is most currently operating at the particular location will be included in case there are operations occurring at the site.
- *Site Name*: identifies the site by a title, which represents the name of the operation or deposit at the location. For instance, specific titles or descriptions of production facilities and corporate offices will be included.

9.2.2 Geographic location

- *Country*: name of the country in which the site is located.
- *City*: more in-depth political state, province, or territory within the country that the construction resource is located in.
- *Latitude*: geographic latitude of the site represented in decimal degrees and WGS84 Web Mercator projection.
- *Longitude*: geographic longitude of the site represented in decimal degrees and WGS84 Web Mercator projection.
- *Precision*: preciseness of the latitude-longitude location. This is defined by the following characters:
 - S: latitude-longitude coordinate pair that represents the exact site location.
 - A: approximate location of an individual site provided as a latitude-longitude coordinate pair, which may be represented by a region or city if limited information is available.

- C: cluster of sites to represent the characteristics of a region or city, represented as latitude-longitude coordinate pair.

9.2.3 Site characteristics

- *Construction resource*: commodity produced at the site, such as a deposit or resource, regardless of operation.
- *Product*: specific type of commodity produced at the site.
- *Industry type*: the type of operations occurring at the site including the following three categories:
 - *Seasonal*: variations exist in the production and/or consumption of the material based on the season.
 - *Cyclical*: variations exist in the production and/or consumption of the material based on business cycles.
 - *Regular*: no variations occur due to effects from either seasons of the year or the cyclical industry behavior effects, as outlined above.
- *Site type*: type of operation most currently existing at the site; these operational types include four different categories:
 - *Office*: corporate offices locations, which are an important part in the control and operations of processing. This category omits offices specifically for sales.
 - *Plant*: plants, factories, and other manufacturing sites where raw materials are transformed into the final product.
 - *Terminal*: terminals and shipping ports where the product is stored for future distribution as well as where the product is imported or exported.
 - *Deposit*: mines, natural resource, and other raw material deposits where raw materials are extracted or available for excavation.
- *Capacity*: amount of a commodity that is possible to produce at the plant for a given construction resource. This amount does not reflect the actual capacity, but rather is based on what is installed on site.
- *Units*: unit of measurement for facility's capacity, if that is provided.
- *Employees*: exact or approximate number of workers at the site.
- *Quality*: grade of the product prepared at the plant.
- *Electric requirements*: electrical power used by the plant, represented in megawatts. Power may originate on-site or from the national grid.
- *Electric requirement source*: provides location where electricity originates from
- *Import*: source of imported materials to produce commodities, if imported.
- *Notes*: any additional and pertinent information about the site.

10 Conclusions and Recommendations

Construction of military facilities is one of the most important aspects of military missions, and this effort is designed to develop a GIS-based decision support tool to assist in siting FOBs in theater. In all, the availability of locally sourced materials and their suitability for supporting the military mission were analyzed for the Maiduguri, Nigeria, region. The methodology for that analysis took into account 19 different variables. Key factors included in the analysis and determination of materials and location included local materials accessibility, quality, and quantity; local transportation infrastructure; and population densities. This case study is unique due to Maiduguri's relatively isolated high level of population and hostility in the region, and special care was taken to account for these factors. The effective proximity factor also allowed for the central locations of each construction resource within the respective regions to be determined and tied into each other. It was determined that brick is the most widely used and trusted construction material in the region.

Overall, this case study serves as an example of creating a materials database and methodology for a potentially hostile region. Every region will have a unique methodology; however, other regions can be adapted from this case study's methodology.

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References

- Abdullahi, Mohammed. 2006. "Properties of Some Natural Fine Aggregates in Minna, Nigeria and Environs" *Leonardo Journal of Sciences* 8: 1-6. Accessed 12 January. http://ljs.academicdirect.org/A08/01_06.htm.
- Adesogan, S. Olu. 2013. "Wooden Materials in Building Projects: Fitness for Roof Construction in Southwestern Nigeria." *Journal of Civil Engineering Construction Technology* 4(7): 217-223.
- Adewole, Kazeem Kayode, Wasiu Olbanji Ajagbe, and Idris Ademola Arasi. 2015. "Determination of Appropriate Mix Ratios for Concrete Grades Using Nigerian Portland-Limestone Grades 32.5 and 42.5." *Leonardo Electronic Journal of Practices and Technologies* 26: 79-88.
- Adewole, Kazeem K., Festus A. Olutoge, and Hamzat Habib. 2014. "Effect of Nigerian Portland-Limestone Cement Grades on Concrete Compressive Strength." World Academy of Science, Engineering and Technology. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering* 8(11): 1199-1202.
- African Development Bank Group. 2013. "An Infrastructure Action Plan for Nigeria: Closing the Infrastructure Gap and Accelerating Economic Transformation." Map. Accessed 26 April. http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/An_Infrastructure_Action_Plan_for_Nigeria_-_Closing_the_Infrastructure_Gap_and_Accelerating_Economic_Transformation.pdf.
- "Ajaokuta Steel Company Limited." 2016. Accessed 7 March. <http://www.ajaokutasteel.com/site/index.php>.
- Ajayi, John Ade, Michael A. Adegbite, and Abimbola R. Iyanda. 2014. "Sustainable Iron and Steel Production in Nigeria: The Techno-Economic Backbone of the National Development." http://www.wfeo.org/wp-content/uploads/wecsi2014/B1/B1-1.MAINPAPER-Steel_for_Sustainable_Development-AdeAjayi.pdf.
- Al-Chaar, Ghassan K., George W. Calfas, Michael A. Weiss, Michael K. Valentino, and Patrick J. Guertin. 2016. *Construction Material-Based Methodology for Military Contingency Base Construction: Case Study of Dhaka, Bangladesh*. ERDC/CERL TR-16-14. Champaign, IL: Engineer Research and Development Center – Construction Engineering Research Laboratory.
- Aluko, Mobolaji. 2015. "Nigeria Now Has 21 Functional Steel Mills." <https://www.proshareng.com/news/Commodities/Nigeria-now-has-21-functional-steel-mills---See-Distribution/25792>.
- Apebo, N.S., M.B. Iorwua, and J.C. Agunwamba. 2013. "Comparative Analysis of the Compressive Strength of Concrete with Gravel and Crushed Over Burnt Bricks as Coarse Aggregates." *Nigerian Journal of Technology* 32(1): 7-12.

- Arinze, N.A., M.N. Dammo, A. Isa, J.M. Deborah, Adji A. Band, and G.B. Yusuf. 2015. "Challenges Regarding Management Practice Of Cement On Construction Sites North-Eastern Nigeria." *International Journal of Engineering Inventions* 4(8): 23–26.
- ASCE/SEI 31-03. 2003. *Seismic Evaluation of Existing Buildings*. Reston, VA: American Society of Civil Engineers. <http://dx.doi.org/10.1061/9780784406700>
- ASTM C33/C33M. "Standard Specification for Concrete Aggregates." West Conshohocken, PA: ASTM International.
- ASTM C136/136M. "Standard Testing Method for Sieve Analysis of Fine and Coarse Aggregate." West Conshohocken, PA: ASTM International.
- Atanda, J. 2015. "Environmental Impacts of Bamboo As a Substitute Constructional Material in Nigeria." *Case Studies in Construction Materials* 3: 33–39. doi:10.1016/j.cscm.2015.06.002.
- "Bayrem Group International." 2016. Accessed 6 February. <http://www.bayremgroup.8k.com/index.html>.
- "Bellet Construction Plc." 2016. Accessed 5 February. <http://www-storefine.wood-me.com/company/bellet-construction-plc-84673>.
- "Bissy King Int. Ltd." . 2016. Accessed 5 February. <http://www-storefine.wood-me.com/company/bissy-king-int-ltd-82194>.
- "BUA Group - Home." 2016. Accessed 18 January 2016. <http://www.buagroup.com/>.
- "Cement Company of Northern Nigeria: Sokoto Cement." 2016. Accessed 17 January. <http://www.sokotocement.com/>.
- "Cimencam." 2016. Accessed 15 January. <http://www.cimencam.com/wps/portal/cm/homepage>.
- "Ciments de L'afrique Cameroun." 2016. Accessed 13 January. <http://www.cimentsafrique.com/>.
- "Cosource Ventures." 2016. Accessed 6 February. <http://www.wood-me.com/company/cosource-ventures-79911>.
- "Dangote Group: Welcome." 2016. Accessed 12 January. <http://dangote.com/>.
- "Dangote Group: Steel." 2016. Accessed 8 March. <http://dangote.com/ourbusinesses/steel.aspx>.
- Darity, William A. 2008. "Steel Industry." In *International Encyclopedia of the Social Sciences*, second edition. Detroit: Macmillan Reference USA. Accessed 25 February. <http://dx.doi.org/10.1108/09504120810905060>.
- "Delta Forestry." 2016. Accessed 5 February. <http://www.worldwoodtrade.com/sell/companydetails/Delta%20Forestry/>.
- "Eddy Bros Nig Ltd." 2009. Accessed 5 February. <http://www.worldwoodtrade.com/sell/companydetails/eddy%20bros%20nig%20ltd/>.

- “EG Wood Ltd.” 2016. Accessed 5 February.
<http://www.worldwoodtrade.com/sell/companydetails/EG%20WOODS%20LTD/>.
- “Ekam Quarry Nigeria Limited.” 2016. Accessed 11 January.
http://ng.sidolocal.com/business_services/13934/ekam-quarry-nigeria-limited.
- “Epe Plywood Industries Limited.” 2016. Accessed 17 February.
<http://oduainvestment.com.ng/epe-plywood-industries-limited/>.
- “Exploration Licence.” 2016. Nigerian Mining Cadastre Office. Accessed 16 January.
http://miningcadastre.gov.ng/pages/pub/pdf/MCO_Title_Holders_3-29-2011.pdf.
- “Extant Grants.” Federal Republic of Nigeria. Mining Cadastre Office. 2016. Accessed 12 January. http://miningcadastre.gov.ng/pages/pub/pdf/Grants_Notice_28-11-2011.pdf.
- “Fordaq: The Timber Network.” 2016. Accessed February 18. <http://www.fordaq.com/>.
- “Forestry.” Federal Ministry of Environment. 2016. Accessed 6 February.
<http://environment.gov.ng/index.php/about-moe/departments-agencies/technical-department/fdf>.
- “GoldenLand Resource Int. Ltd.” 2016. Accessed 15 January. <http://www.goldenland.com.ng/>.
- Graham and Trotman Limited. 1983. *Major Companies of Nigeria 1983*. Association of British Directory Publishers.
- “Hephzibah Resc and Inv Ltd.” 2016. Accessed 6 February. <http://hephzibah-resc-inv-ltd.wood-me.com/>.
- “Ibeto Group.” 2016. Accessed 28 January. <http://ibeto.com/IBETO-home.asp?P=1>.
- IBP (International Business Publications). 2015. *African Countries Mineral Industry Handbook Volume 1: Strategic Information and Regulations*. World Business and Investment Library series. Self-published: Lulu.com
- “The Impacts of Forest Industries and Wood Utilization on the Environment.” 2016. Food and Agriculture Organization of the United Nations. Accessed 17 February.
<http://www.fao.org/docrep/ARTICLE/WFC/XII/0122-A2.HTM>.
- “International Cement Review.” 2016. Accessed 17 January. <http://www.cemnet.com/>.
- “Jasper Wood Industry.” 2016. Accessed 6 February. <http://jasper-wood-industry.wood-me.com/>.
- Jock, A.A., F.A. Ayeni, L.S. Jongs, and N.S. Kangpe. 2013. “Development of Refractory Bricks from Nigerian Nafuta Clay Deposit.” *International Journal of Materials, Methods and Technologies* 1(10): 189–195.
- “JORC (Joint Ore Reserves Committee).” 2016. Accessed 27 February. <http://www.jorc.org/>.
- Ju, Ezeokonkwo, and Anyanechi CN Ifeanyi. 2015. “Assessment of Quality of Cement in Nigerian Market and the Controversy of Building Collapse.” *Journal of Scientific and Engineering Research* 2(1):22–27.

- “Lafarge in Nigeria - Cement.” 2016. Accessed 17 January.
<http://www.lafarge.com.ng/wps/portal/ng/2-Cement>.
- “Macmahon Holdings Limited | Mining & Construction Australia.” 2016. Accessed 14 January. <http://www.macmahon.com.au/>.
- “Malagas Ventures Nig.” 2016. Accessed 6 February. <http://malagas-ventures-nig.wood-me.com/>.
- M.F.W. Dredging and Marine (Nigeria) Limited.” 2016. Accessed 16 January.
<http://mfwdredgingng.com/>.
- NCP 01:1973. 1973. “The Structural Use of Concrete in Building.” Federal Capital Territory, Abuja, Nigeria: Federal Republic of Nigeria National Assembly (NASS).
- “Nigeria Gas and Steel Ltd.” Company List. 2016. Accessed 8 March.
https://companylist.org/Details/11562947/Nigeria/Nigeria_Gas_and_Steel_Ltd/.
- NIS 117:1983. 1983. “Standards on Steel Bars for Reinforcement of Concrete.” Lekki Peninsula, Lagos: Standards Organisation of Nigeria.
- NIS 197:1984. 1984. “Specifications for Structural Steel.” Lekki Peninsula, Lagos: Standards Organisation of Nigeria.
- NIS 199:1984. 1984. “Methods of Testing Steel.” Lekki Peninsula, Lagos: Standards Organisation of Nigeria.
- NIS 256:1982. 1982. “Standard Method of Testing Fresh Concrete.” Lekki Peninsula, Lagos: Standards Organisation of Nigeria.
- NIS 444-1:2003. 2003. “Cement: Part 1 – Composition, Specification and Conformity Criteria for Common Cement.” Lekki Peninsula, Lagos: Standards Organisation of Nigeria.
- NIS 444-2:2003. 2003. “Cement: Part 2 – Conformity Evaluation.” Lekki Peninsula, Lagos: Standards Organisation of Nigeria.
- NIS 455:2003. 2003. “Method of Testing Cement – Chemical Analysis of Cement.” Lekki Peninsula, Lagos: Standards Organisation of Nigeria.
- NIS 499:2004. 2004. “Standards for Iron and Steel.” Lekki Peninsula, Lagos: Standards Organisation of Nigeria.
- Nigeria, Federal Republic of. 2006. *National Building Code*. South Africa: LexisNexis Butterworths. Accessed 7 March 2016.
sdngnet.com/.../National%20Building%20Code%20of%20Nigeria%202006.pdf.
- Nigeria, Federal Republic of. January 2014. “Nigeria Industrial Revolution Plan,” Release 1.0. Accessed 25 February 2016. <http://www.nepza.gov.ng/downloads/nirp.pdf>.
- “Nigeria Forest Information and Data.” 2016. Accessed 4 February.
<http://rainforests.mongabay.com/deforestation/2000/Nigeria.htm>.

- Nigeria Population Commission. 2016. "State Population." <http://population.gov.ng/index.php/state-population>.
- "Nigeria States – Nigeria maps." 2016. Accessed 27 June. <http://mapsof.net/nigeria/nigeria-states>.
- Nkeki, Felix N., Philip J. Henah, and Vincent N. Ojeh. 2013. "Geospatial Techniques for the Assessment and Analysis of Flood Risk along the Niger-Benue Basin in Nigeria." *Journal of Geographic Information System* 5(2): 123–135. Accessed 26 April 2016. <http://dx.doi.org/10.4236/jgis.2013.52013>.
- "Obijiwealth Nig Ltd." 2016. Global Wood. Accessed 6 February. <http://www.globalwood.org/company/mgodetail.asp?id=14869>.
- Obikwelu, D. O. N., and C.O. Nebo. 2012. "A Critical Look at the Nigerian Steel Industry—A Dark Page on the History of Nigeria and the Metallurgical Profession." Nsukka, Nigeria: University of Nigeria. <http://www.nigerianmetsociety.org/wp-content/uploads/2015/02/Critical-look-at-the-Nigerian-Steel-Industry-BY-D.-O.N.-Obikwelu-and-C.O.-Nebo.pdf>.
- Ohagwua, C.J., and B.O. Ugwuishiwub. 2011. "Status of Wood Processing and Storage in Nigeria." *Nigerian Journal of Technology* 30(2) 94–104.
- Ohimain, Elijah I. 2013. "Scrap Iron and Steel Recycling in Nigeria." *Greener Journal of Environment Management and Public Safety* 2(1): 001–009.
- Okunomo, K., and F. O. Achoja. 2010. "Economic Impact Assessment of African Timber And Plywood Company in Sapele, Delta State, Nigeria." *African Journal of General Agriculture* 6(3): 159–167.
- "Orlean Farms Ltd." 2016. Accessed 6 February. <http://www.worldwoodtrade.com/sell/companydetails/Orlean%20Farms%20Ltd/>.
- Otoko, George Rowland. 2014. "The Use of Laterites for Production of Soil-Cement Blocks." *International Journal of Engineering and Technology Research* 2(4):1–11.
- "PW Group." 2016. Accessed 15 January. <http://www.pwlimited.com/>.
- "QuickMix | Home." 2016. Accessed January 18. <http://quickmixnigeria.com/>.
- "Ratcon Construction Company Limited." 2016. Accessed January 21. <http://www.ratconconstruction.com/>.
- "RCC Nigeria." 2016. Accessed 13 January. <http://www.rccnigeria.com/>.
- "Reagan Cement Bagging Company commences operation – Business - Nairaland." 2016. Accessed 18 January. <http://www.nairaland.com/1348368/reagan-cement-bagging-company-commences>.
- "Review and Improvement of Data Related to Wood-Products in Nigeria." 2016. Food and Agriculture Organization of the United Nations. Accessed 17 February 2016. <http://www.fao.org/docrep/004/X6762E/X6762E00.htm#TOC>.

- “Salimonu Company Nigeria Ltd.” 2016. Accessed 15 January. <http://www.salimonu.com/>.
- “Sehnaoui Plant.” 2016. Accessed 12 January. <http://sehnaouiplant.com/home-page/nigeria/>.
- “Shamen Global Concepts Ventures.” 2016. Accessed 6 February. <http://www.worldwoodtrade.com/sell/companydetails/SHAMEN%20GLOBAL%20CONCEPTS%20VENTURES/>.
- Shmulsky, Rubin. 2002. “Wood and Wood Products.” Accessed 6 February 2016. http://www.encyclopedia.com/topic/Wood_products.aspx.
- “Shnahan Trading Investment.” 2016. Accessed 6 February. <http://www.worldwoodtrade.com/sell/companydetails/Shnahan%20Trading%20Investment/>.
- Sholanke, Anthony Babatunde, Olabozipo I. Fagbenle, P.A. Aderonmu, and Akintunde M. Ajagbe. 2015. “Sandcrete Block and Brick Production in Nigeria - Prospects and Challenges.” *IIARD International Journal of Environmental Research* 1(4): 1–17.
- “Sika Manufacturing Nigeria Ltd.” 2016. Accessed 13 January. <http://nga.sika.com/>.
- “SON to Enforce Stricter Measures on Errant Steel Producers.” 2016. Accessed 10 March. <http://www.thisdaylive.com/index.php/2016/03/08/son-to-enforce-stricter-measures-on-errant-steel-producers/>.
- “SPG Nigeria Limited.” 2016. Accessed 15 January. <http://spgnigeria.com/>.
- “Stanimose.” 2016. Accessed 6 February. <http://www.worldwoodtrade.com/sell/companydetails/Stanimose/>.
- Sumaila, Abdul Ganiu Femi. 2013. “Analysis of Cement Market in Northern Nigeria.” *International Journal of Marketing Studies* 5(1): .34–41. <http://dx.doi.org/10.5539/ijms.v5n1p34>.
- “TOP Steel Nigeria Limited.” 2016. Accessed 7 March. <http://www.topsteelnig.com/>.
- “Tradecorp Investments Nigeria Ltd.” 2016. Accessed 6 February. <http://www.worldwoodtrade.com/sellandbuy/companydetails/TRADECORP%20INVESTMENTS%20NIGERIA%20LIMITED/>.
- “Ulman Investment Nig Ltd.” 2016. Accessed 6 February. <http://ulman-investment-nig-ltd.wood-me.com/>.
- USDA Forest Service. 2010. *Wood Handbook: Wood as an Engineering Material*. Central Edition. Madison, WI: USDA Forest Service, Forest Products Laboratory.
- “Welcome to Eastern Bulkcem Company Limited!” 2016. Accessed 13 January. <http://eaglecement.com.w3cdomain.com/>.
- “Welcome Julius Berger Nigeria.” 2016. Accessed 12 January. <http://www.julius-berger.com/about-us/our-profile/>.
- “Welcome to Total Mining Limited | Mining.” 2016. Accessed 13 January. <http://totalminingltd.com/>.

“Wood’vantage Ltd.” 2016. Accessed 6 February. <http://www.wood-me.com/company/wood-vantage-ltd-83393>.

World Bank Group. 2016. “Population Density (people per sq. km of land area).” Accessed 27 June. <http://data.worldbank.org/indicator/EN.POP.DNST>.

“Yemi Productions Ltd.” 2016. Accessed 6 February. <http://www.worldwoodtrade.com/sell/companydetails/yemi%20productions%20ltd/>.

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Appendix: Population Data and Construction Materials Database

The material provided in this appendix adds data of how the methodology was created in regard to the population of various cities. Table A1–Table A6 provide each of the Nigerian states in each region with corresponding population and area, which were used to calculate each region’s density.

Along with this information, the construction materials database is provided as a reference to the reader (Table A7–A12).

Table A1. Region 1 - Northwest density (Nigeria Population Commission 2016).

State	Population	Area (sq. km)
Abuja	1,406,239	7,315
Kaduna	6,113,503	46,053
Kebbi	3,256,541	36,800
Niger	3,954,772	76,363
Sokoto	3,702,676	25,973
Zamfara	3,278,873	39,762
<i>Region Total</i>	<i>21,712,604</i>	<i>232,266</i>
Region 1 density (people/sq. km) = 93.5		

Table A2. Region 2 – Southwest density (Nigeria Population Commission 2016).

State	Population	Area (sq. km)
Bayelsa	1,704,515	10,773
Delta	4,112,445	17,698
Edo	3,233,366	17,802
Ekiti	2,398,957	6,353
Kogi	3,314,043	29,833
Kwara	2,365,353	36,825
Lagos	9,113,605	3,345
Ogun	3,751,140	16,792
Ondo	3,460,877	14,606
Osun	3,416,959	9,251
Oyo	5,580,894	28,454
<i>Region Total</i>	<i>42,452,154</i>	<i>191,732</i>

State	Population	Area (sq. km)
Region 2 density (people/sq. km) = 221.4		

Table A3. Region 3 – Northcentral density (Nigeria Population Commission 2016).

State	Population	Area (sq. km)
Bauchi	4,653,066	45,837
Gombe	2,365,040	18,768
Jigawa	4,361,002	23,154
Kano	9,401,288	20,131
Katsina	5,801,584	24,192
Plateau	3,206,531	30,913
<i>Region Total</i>	<i>29,788,511</i>	<i>162,995</i>
Region 3 density (people/sq. km) = 182.8		

Table A4. Region 4 - Southcentral density (Nigeria Population Commission 2016).

State	Population	Area (sq. km)
Abia	2,845,380	6,320
Akwa Ibom	3,902,051	7,081
Anambra	4,177,828	4,844
Benue	4,253,641	34,059
Cross River	2,892,988	20,156
Ebonyi	2,176,947	5,670
Enugu	3,267,837	7,161
Imo	3,927,563	5,530
Nasarawa	1,869,377	27,117
Rivers	5,198,716	11,077
<i>Region Total</i>	<i>34,512,328</i>	<i>129,015</i>
Region 4 density (people/sq. km) = 267.5		

Table A5. Region 5 – Eastern density (Nigeria Population Commission 2016).

State	Population	Area (sq. km)
Adamawa	3,178,950	36,917
Borno	4,171,104	70,898
Taraba	2,294,800	54,473
Yobe	2,321,339	45,502
<i>Region Total</i>	<i>11,966,193</i>	<i>207,790</i>
Region 5 density (people/sq. km) = 57.6		

**Table A6. Region 6 – largest neighboring city density
(Nigeria Population Commission 2016).**

Region	Population	Area (sq. km)
Lac	433,790	21,500
Chari-Baguirmi	578,425	47,000
Hadjer-Lamis	566,858	30,000
Mayo-Kebbi Est	774,782	18,350
N'Djamena	951,418	500
<i>Region Total:</i>	<i>3,305,273</i>	<i>117,350</i>
Region 6 density (people/sq. km) = 28.2		

Table A7–Table A12 provide the Construction Materials Database, by material, for the region of Maiduguri, Nigeria. Refer to Section 9.2 for details about the information in each column. Some cells in some of the following tables have no information (blank) due to lack of availability of information and/or validation of information. Along with this, not all columns are the same for every table due to variability of existing information regarding each material. Each material's construction material database was limited to contain only those columns that had information provided and thereby reducing the redundancy of several blank columns.

Table A7. Construction materials database — aggregate (ERDC-CERL).

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Name	Site Type	Capacity (MTPA)	Notes
Cameroon	Figuil	8.86	13.11	S	Cinencam	Limestone aggregate	Regular	Unconsolidated material	Mine	0.272	
Chad	Chari	12.967	14.517	S	None	Coarse aggregate	Regular	Unconsolidated material	Mine	0.3	
Chad	Logone Rivers	12.967	14.517	S	None	Coarse aggregate	Regular	Unconsolidated material	Mine	0.3	
Chad	Louga	12.533	19.25	S	Société d'Exploitation Minière de Pala	Limestone aggregate	Regular	Unconsolidated material	Quarry		
Chad	Mani	12.733	14.683	S	Société Tchadienne d'Exploitation des Carrières	Crushed Stone	Regular	Dandi Quarry	Quarry		
Nigeria	Adazi Nnukwu	6.10198	7.012367	A	Adazi Nnukwu Town Development Union	Sand	Regular	Unconsolidated material	Mine		
Nigeria	Akampka	5.310394	8.356934	S	Julius Berger	Coarse aggregate	Regular	Akampka Quarry	Quarry		
Nigeria	Akingbile Village	7.512747	3.912589	S	Reynolds Construction Company	Crushed Coarse aggregate	Regular	Ibadan Office	Office		Akingbile Village, Ibadan, Nigeria
Nigeria	Akpajo Eleme	4.813484	7.092221	A	M. F. W. Dredging & Marine Nigeria Limited	River Sand	Regular	Unconsolidated material	Mine		
Nigeria	Aniocha	6.182404	6.525235	A	Anthony Chizea Holding	Sand	Regular	Unconsolidated material	Mine		
Nigeria	Arochukwu	5.39411	7.903566	A	Reagan Renaissance Limited	Limestone aggregate	Regular	Arochukwu Quarry	Mine		

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Name	Site Type	Capacity (MTPA)	Notes
Nigeria	Calabar	4.981725	8.324597	S	Macmahon	Limestone aggregate	Regular	Ekam Quarry	Quarry		No 1 Barracks Road, Nigon House, Calabar, Cross river
Nigeria	Chanchanga	9.573678	6.661366	S	None	Fine aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Dogo	8.083583	11.217104	S	None	Fine aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Ebonyi	6.238736	8.027062	A	Ebonyi Cement Company	Limestone aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Ewekoro	6.93602	3.22247	S	Macmahon	Limestone aggregate	Regular	Ewekoro Quarry	Quarry		
Nigeria	Ewekoro	6.935639	3.223329	A	Gateway Mining Company Limited	Limestone aggregate	Regular	Ewekoro Quarry	Mine		1 Toyibat Yusuf Adeniji St Medina Estate, Lagos
Nigeria	Gusau	12.16239	6.674451	A	S. Pawa Quarry	Sand	Regular	Unconsolidated material	Mine		Zaria Rd, Zaria, Kaduna, Nigeria
Nigeria	Gwada	9.766418	6.841847	S	None	Fine aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Ifo	6.818554	3.193005	A	Gateway Holdings Limited	River Sand	Regular	Unconsolidated material	Mine		
Nigeria	Ijumu	7.566667	6.0833	S	Total Mining Limited	Limestone aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Ikeja	6.602178	3.350776	A	Ratcon Construction Company Limited	aggregate	Regular	Unconsolidated material	Quarry		Ikija Quarry, KM. 19, Ibadan-Lagos Expressway, Near Ogunmakin Ibadan, Oyo State.
Nigeria	Jabi District	9.064319	7.426993	S	Reynolds Construction Company	Crushed Coarse aggregate	Regular	Head Office	Office		P.M. Box 5059, 28 Ebitu Ukiwe Street, Jabi District., Abuja FCT, Nigeria
Nigeria	Kaduna	10.513122	7.414869	A	Total Mining Limited	Sand	Regular	Unconsolidated material	Mine		Multiple locations of sand deposits available in Kaduna
Nigeria	Kodo	4.952367	8.34789	A	None	Fine aggregate	Regular	Unconsolidated material	Mine		

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Name	Site Type	Capacity (MTPA)	Notes
Nigeria	Kuje	8.876876	7.244965	A	Association Of Tipper & Quarry Owners of Nigeria	Sand	Regular	Unconsolidated material	Mine		
Nigeria	Lagos	6.520251	3.370035	A	Salimonu Company Nigeria Ltd.	Coarse aggregate	Regular	Salimonu Granite Stones	Office		P.O Box 3122 Surulere Lagos.
Nigeria	Lagos	6.520251	3.370035	A	Sehnaoui Plant	Coarse aggregate	Regular	Sehnaoui Plant Nigeria Ltd	Office		Lagos, 537, Aina Akingbala Street, Omole Phase 2
Nigeria	Maikunkele	9.68756	6.474902	S	None	Fine aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Maitama Abuja	9.059446	7.420269	S	PW Group	Coarse aggregate	Regular	PW Nigeria Limited	Office		Plot 9, Outer Northern Expressway, Maitama Abuja, FCT
Nigeria	Mpape	9.142213	7.48693	S	Julius Berger	Coarse aggregate	Regular	Mpape Quarry	Quarry		
Nigeria	Nkalagu	6.5167	7.8167	S	None	Limestone aggregate	Regular	Sedimentary Material	Quarry		
Nigeria	Ogbere	6.798683	3.896812	S	Julius Berger	Coarse aggregate	Regular	Ogbere Quarry	Quarry		
Nigeria	Okene	7.561608	6.243024	A	Total Mining Limited	Limestone aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Oko-Eko	6.534777	3.392708	A	Ratcon Construction Company Limited	aggregate	Regular	Unconsolidated material	Quarry		Oko-eko Village, Off Benin-Shagamu
Nigeria	Orile	6.478429	3.34392	A	Ratcon Construction Company Limited	aggregate	Regular	Unconsolidated material	Quarry		Orile Quarry, Off Ibadan-Ijebu Ode Road, Orile Village, Ibadan, Oyo State.
Nigeria	Oshimili South Delta	6.117573	6.658964	A	Golden Land Resources International Limited	River Sand	Regular	Unconsolidated material	Mine		
Nigeria	Paiko	9.435218	6.633854	S	None	Fine aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Port Harcourt	4.823385	6.955577	S	PW Group	Coarse aggregate	Regular	PW Marine Limited	Office		Rumuolumeni, Port Harcourt, Rivers State, Nigeria

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Name	Site Type	Capacity (MTPA)	Notes
Nigeria	Pyata	6.554553	3.371022	A	None	Fine aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Shata	8.000567	7.843389	S	None	Fine aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Sokuro	7.353337	3.920161	A	Ratcon Construction Company Limited	aggregate	Regular	Unconsolidated material	Quarry		Sokuro Village, KM. 7 Ibadan-Lagos Expressway, Near Toll-gate, Oyo State.
Nigeria	Takuti	9.178251	6.541804	S	None	Fine aggregate	Regular	Unconsolidated material	Mine		
Nigeria	Victoria Island	6.428435	3.412189	S	Reynolds Construction Company	Crushed Coarse aggregate	Regular	Lagos Office	Office		Plot 1715 Idejo Street, Victoria Island, Lagos, Nigeria
Nigeria	Zaria	11.101	7.7023	S	None	Fine aggregate	Regular	Unconsolidated material	Quarry		
Nigeria	Zaria	11.101	7.7023	S	None	Coarse aggregate	Regular	Unconsolidated material	Quarry		Granite Rock - Crushed Coarse Aggregate

S = exact site location; A = approximate site location; C = cluster of sites.

Table A8. Construction materials database – cement (ERDC-CERL).

Country	City	Latitude	Longitude	Precision*	Company	Industry Type	Site Name	Site Type	Capacity (MTPA)	Electrical Requirement (mW)
Benin	Adja-Ouere	7.048326	2.607567	A	Layousse, Les Ciments Du Sahel	Regular	Nouvelle Cimenterie du Bénin - NOCIBE	Plant	1.7	
Benin	Cotonou	6.35	2.433	S	Societe des Ciments du Benin	Regular	Cotonou Cement Plant	Plant	0.2	
Benin	Cotonou	6.35	2.433	S	Heidelberg Cement	Regular	Cimbenin S A - Cimbenin - Cotonou	Plant	0.275	
Benin	Onigbolo	7.185665	2.649628	A	Societe des Ciments d'Onigbolo	Regular	Onigbolo Cement Plant	Plant	0.45	
Cameroon	Bonabéri	5.133	14	S	Les Cimenteries du Cameroun (CIMENCAM)	Regular	Bonaberi Cement Plant	Plant	1.3	

Country	City	Latitude	Longitude	Precision*	Company	Industry Type	Site Name	Site Type	Capacity (MTPA)	Electrical Requirement (mW)
Cameroon	Douala	4.050969	9.761714	A	Ciments de L'Afrique Cameroun SA	Regular	Douala Cement Plant	Plant	0.5	
Cameroon	Figuil	9.76508	13.965506	S	Les Cimenteries du Cameroun (CIMENCAM)	Regular	Figuil Cement Plant	Plant		
Cameroon	Port of Douala	4.035733	9.677533	A	Dangote Cement	Regular	Cameroon Cement Plant	Plant	1.5	
Chad	Bissi Keda	10.842212	15.318028	A	Sonacine Usine	Regular	Sonacine Usine Plant	Plant		
Chad	Baoare	9.244954	14.419394	A	Chad Baoare Cement	Regular	Baoare Cement Pant	Plant	0.2	
Chad	N'Djamena	12.136657	15.050933	A	Ciment de l'Afrique	Regular	Chad Cement Plant	Plant		
Chad	N'Djamena	12.136657	15.050933	A	CIMENTCHAD	Regular	N'Djamena Cement Plant	Plant		
Chad	N'Djamena	12.136657	15.050933	A	Société Nationale de Cimenterie	Regular	Société Nationale de Cimenterie Plant	Plant		
Niger	Keita	14.839692	5.934818	A	Dangote Cement	Regular	Niger Cement Plant	Plant	1.5	
Niger	Malbaza	13.945	5.522	S	Société Nigérienne de Cimenterie S.A. (SNC)	Regular	Malbaza Cement Plant	Plant	0.037	
Nigeria	Aliko Inland	6.520251	3.370035	A	Dangote Cement	Regular	Aliko Inland Cement Terminal	Terminal		
Nigeria	Arochukwu	5.39411	7.903566	A	Reagan Renaissance Ltd	Regular	Arochukwu Plant	Plant	1.2	
Nigeria	Ashaka	10.899	11.516	S	Lafarge Group	Regular	Ashanka Cement Co. Plc.	Plant		
Nigeria	Benue	7.3323	8.7519	S	Dangote Cement	Regular	Benue Cement Company Plc Factory Estate	Office	0.9	
Nigeria	Benue	7.369361	9.036357	S	Dangote Cement	Regular	Benue Cement Company Limited	Plant	4	
Nigeria	Calabar	5.08321	8.51721	S	Lafarge Group	Regular	United Cement Company of Nigeria	Plant	2.5	

Country	City	Latitude	Longitude	Precision*	Company	Industry Type	Site Name	Site Type	Capacity (MTPA)	Electrical Requirement (mW)
Nigeria	Damaturu	11.747376	11.965355	A	Lafarge Group	Regular	AshakaCem Plc Branch	Plant	0.9	
Nigeria	Ewekoro	6.9	3.217	S	Lafarge Group	Regular	WAPCO Operations - Ewekoro Cement Plant	Plant	1.5	
Nigeria	Ibese	7.010005	3.049932	S	Dangote Cement	Regular	Dangote Cement PLC	Plant	12	111
Nigeria	Ikeja	6.602178	3.350776	A	Lafarge Group	Regular	Lafarge Readymix Nigeria	Plant		
Nigeria	Itori	6.902786	3.207497	S	Lafarge Group	Regular	WAPCO Operations	Plant	1	
Nigeria	Kano	12.002467	8.542583	S	Cement Company of Northern Nigeria Plc	Regular	Sokoto Cement	Plant	0.25	
Nigeria	Lagos	6.444831	3.427114	S	Dangote Cement	Regular	Dangote and Benue Cement Plant	Office		
Nigeria	Lagos	6.442734	3.410298	S	Eastern Bulkcem Company Ltd	Regular	Eastern Bulkcem Company Office	Office		
Nigeria	Lagos	6.520251	3.370035	A	Dangote Cement	Regular	Lagos Cement Terminal	Terminal	3	
Nigeria	Lagos	6.520251	3.370035	A	Dangote Cement	Regular	Continental Cement Terminal	Terminal		
Nigeria	Nkalagu	6.483	7.767	S	Nigeria Cement Co.	Regular	Nkalagu Cement	Plant	0.6	
Nigeria	Obajana	7.927505	6.42475	S	Dangote Cement	Regular	Obajana Cement Plc	Plant	13.25	135
Nigeria	Okpella	7.308956	6.371523	S	Bua Cement	Regular	BUA Cement OBU Plant	Plant		
Nigeria	Onne	4.723528	7.151133	A	Dangote Cement	Regular	Onne Cement Terminal	Terminal		
Nigeria	Port Harcourt	4.796967	6.94348	S	Eastern Bulkcem Company Limited	Regular	Eagle Cement	Plant	1	
Nigeria	Port Harcourt	4.813556	7.054485	A	Dangote Cement	Regular	Port Harcourt Cement Terminal	Terminal		
Nigeria	Rivers	4.698606	7.158803	S	Lafarge Group	Regular	Atlas Cement	Plant	0.5	
Nigeria	Shagamu	6.831327	3.630466	A	Lafarge Group	Regular	WAPCO Operations	Office		
Nigeria	Shagamu	6.85	3.65	S	Lafarge Group	Regular	WAPCO Operations - Shagamu Cement Plant	Plant	0.6	
Nigeria	Sokoto	8.45	4.433	S	Cement Company of Northern Nigeria Plc	Regular	Kalambaina Plant	Plant	0.5	

Country	City	Latitude	Longitude	Precision*	Company	Industry Type	Site Name	Site Type	Capacity (MTPA)	Electrical Requirement (mW)
Nigeria	Victoria Island	6.430122	3.429885	S	Bua Cement	Regular	BUA Group Headquarters	Office		

S = exact site location; A = approximate site location; C = cluster of sites.

Table A9. Construction materials database – concrete (ERDC-CERL).

Country	City	Latitude	Longitude	Precision*	Company	Industry Type	Site Name	Site Type	Notes
Nigeria	Abuja	9.063677	7.338076	S	Lafarge Africa Plc	Regular	Abuja Plant	Plant	
Nigeria	Idu	9.06576	7.342269	S	Ogbebor Concrete Industries Ltd	Regular	Ogbebor Concrete Industries Ltd	Plant	
Nigeria	Lagos	6.470309	3.375102	S	Julius Berger	Regular	Lagos Office	Plant	15 Ijora Causeway, Lagos, P.O. Box 3643
Nigeria	Lagos	6.425518	3.427427	S	Lafarge Africa Plc	Regular	Victoria Island Plant	Plant	Tiamiyu Salvage, Victoria Island, Lagos State, Nigeria
Nigeria	Lagos	6.447348	3.430982	S	Lafarge Africa Plc	Regular	Ikoyi Plant	Plant	27A, Rumens Street, off Bourdillon Road, Ikoyi, Lagos State, Nigeria
Nigeria	Lagos	6.520251	3.370035	A	Lafarge Africa Plc	Regular	Ikeja Plant	Plant	38 Kudirat Abiola Way, Oregun, Ikeja, Lagos State, Nigeria
Nigeria	Lagos	6.520251	3.370035	A	Lafarge Africa Plc	Regular	Lafarge ReadyMix Nigeria Corporate Office	Office	38 Kudirat Abiola Way, Oregun, Ikeja. Lagos- State Nigeria.
Nigeria	Lagos	6.520251	3.370035	A	Sika Group	Regular	Sika Manufacturing Nigeria Limited	Plant	10 Western Industrial Avenue, Lagos-Ibadan Expressway Isheri, Lagos Ogun State 2340, Nigeria
Nigeria	Mushin	6.527278	3.354518	S	Nigerian Concrete Industries Ltd	Regular	Nigerian Concrete Industries Ltd	Plant	
Nigeria	Ogun	6.89331	3.205589	S	Lafarge Africa Plc	Regular	Ewekoro Plant	Plant	
Nigeria	Port Harcourt	4.707384	7.155041	S	Lafarge Africa Plc	Regular	Onne Plant	Plant	
Nigeria	Rivers	4.957673	6.775339	A	Lafarge Africa Plc	Regular	Daewoo Plant	Plant	Petrochemical Camp, Daewoo Plant, Eleme, Rivers State, Nigeria

Country	City	Latitude	Longitude	Precision*	Company	Industry Type	Site Name	Site Type	Notes
Nigeria	Utako	9.064781	7.447464	S	Julius Berger	Regular	Head Office	Plant	10 Shettima A. Munguno Crescent, Utako 900 108, FCT Abuja
Nigeria	Victoria Island	6.43231	3.440494	S	Quick Mix Nigeria Ltd	Regular	QuickMix Nigeria	Plant	
Nigeria	Victoria Island	6.431306	3.426876	A	SPG Nigeria Limited	Regular	SPG Ready Mixed Concrete	Office	
Nigeria	Victoria Island	6.431306	3.426876	A	SPG Nigeria Limited	Regular	SPG Ready Mixed Concrete	Plant	

* S = exact site location; A = approximate site location; C = cluster of sites.

Table A10. Construction materials database – masonry (ERDC-CERL).

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Type
Nigeria	Maiduguri	11.831739	13.145364	C	Nigerian Mining Corporation and Private Entrepreneurs	Clay Brick	Regular	Plant
Nigeria	Jos	9.895393	8.858572	C	Nigerian Mining Corporation	Clay Brick	Regular	Plant
Nigeria	Kano	12.003923	8.588961	C	Nigerian Mining Corporation	Clay Brick	Regular	Plant
Nigeria	Kaduna	10.513122	7.425168	C	Nigerian Mining Corporation	Clay Brick	Regular	Plant
Nigeria	Ibadan	7.375171	3.949487	C	Nigerian Mining Corporation	Clay Brick	Regular	Plant
Nigeria	Abeokuta	7.144702	3.363702	C	Private Entrepreneurs	Clay Brick	Regular	Plant
Nigeria	Ogun State	6.929933	3.305998	C	Private Entrepreneurs	Clay Brick	Regular	Plant
Nigeria	Lagos	6.527677	3.365864	C	Nigerian Mining Corporation and Private Entrepreneurs	Clay Brick	Regular	Plant
Nigeria	Enugu	6.458674	7.543957	C	Nigerian Mining Corporation and Private Entrepreneurs	Clay Brick	Regular	Plant
Nigeria	Okigwe	5.81987	7.340674	C	Private Entrepreneurs	Clay Brick	Regular	Plant

* S = exact site location; A = approximate site location; C = cluster of sites.

Table A11. Construction materials database – steel (ERDC-CERL).

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Name	Site Type	Capacity (TPA)	Electric Requirement (mW)
Nigeria	Abuja	9.075327	7.398464	A	Baoyao Futurelex	Rebar	Regular	Baoyao Futurelex Rolling Mill	Rolling Mill	20,000	
Nigeria	Ajaokuta	7.538286	6.647023	A	Ajaokuta Steel Co. Ltd.	Structural Steel, Rebar	Regular	Ajaokuta Steel Co. Ltd. Integrated Mill	Integrated Mill	1,300,000	110
Nigeria	Aladja-Owian	5.486671	5.810772	A	Delta Steel Co.	Structural Steel, Rebar	Regular	Delta Steel Co. Integrated Mill	Integrated Mill	320,000	
Nigeria	Lagos	6.609158	3.363963	A	Nigeria Gas and Steel Ltd.	Rebar	Regular	Nigeria Gas and Steel Ltd. Steel Mill	Steel Mill	72,000	
Nigeria	Lagos	6.6612	3.51947	A	Top Steel Nigeria Limited	Rebar	Regular	Top Steel Nigeria Limited Integrated Mill	Integrated Mill	219,000	
Nigeria	Asaba	6.206002	6.692592	A	General Steel Mill	Rebar	Regular	General Steel Mill Mini Mill	Mini Mill	50,000	
Nigeria	Eket	4.646663	7.942016	A	Qua Steel Products	Structural Steel	Regular	Qua Steel Products Rolling Mill	Rolling Mill	600,000	
Nigeria	Enugu	6.460379	7.546016	A	Nigersteel Co.	Structural Steel	Regular	Nigersteel Co. Mini Mill	Mini Mill	40,000	
Nigeria	Ibadan	7.379256	3.948113	A	Alliance Steel Co.	Rebar	Regular	Alliance Steel Co. Rolling Mill	Rolling Mill	20,000	
Nigeria	Ikeja	6.602178	3.350776	A	Asiastic Mandarin Ind.	Structural Steel, Rebar	Regular	Asiastic Mandarin Ind. Rolling Mill	Rolling Mill	60,000	
Nigeria	Ikeja	6.602178	3.350776	A	Universal Steel Co.	Structural Steel	Regular	Universal Steel Co. Mini Mill	Mini Mill	80,000	
Nigeria	Ikeja	6.602178	3.350776	A	Continental Iron & Steel Co.	Structural Steel	Regular	Continental Iron & Steel Co. Mini Mill	Mini Mill	150,000	
Nigeria	Ikorodu	6.620119	3.519355	A	Mayor Eng. Co.	Rebar	Regular	Mayor Eng. Co. Rolling Mill	Rolling Mill	220,000	
Nigeria	Ikorodu	6.620119	3.519355	A	Kew Metal Industries	Structural Steel, Rebar	Regular	Kew Metal Industries Mini Mill	Mini Mill	20,000	

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Name	Site Type	Capacity (TPA)	Electric Requirement (mW)
Nigeria	Ilorin	8.478351	4.541221	A	Kwara Commercial, Metal and Chemical Industries	Rebar	Regular	Kwara Commercial, Metal and Chemical Industries Rolling Mill	Rolling Mill	40,000	
Nigeria	Ilorin	8.478351	4.541221	A	Union Steel Co.	Structural Steel	Regular	Union Steel Co. Rolling Mill	Rolling Mill	20,000	
Nigeria	Jos	9.897422	8.857198	A	Jos Steel Rolling Company	Rebar	Regular	Jos Steel Rolling Company Rolling Mill	Rolling Mill	210,000	
Nigeria	Kano	12.000901	8.594111	A	Nigerian Spanish Eng. Co.	Rebar	Regular	Nigerian Spanish Eng. Co. Mini Mill	Mini Mill	100,000	
Nigeria	Katsina	12.982056	7.622589	A	Kastina Steel Rolling Co.	Rebar	Regular	Kastina Steel Rolling Co. Rolling Mill	Rolling Mill	210,000	
Nigeria	Onitsha	6.141404	6.806368	A	Alliance Steel Co.	Rebar	Regular	Alliance Steel Co. Rolling Mill	Rolling Mill	20,000	
Nigeria	Oshogbo	7.781932	4.539818	A	Dangote Steel	Structural Steel, Rebar	Regular	Dangote Steel Rolling Mill	Rolling Mill	400,000	
Nigeria	Otta	7.945253	4.788756	A	Selsametal	Rebar	Regular	Selsametal Rolling Mill	Rolling Mill	100,000	
Nigeria	Otta	7.945253	4.788756	A	Federated Steel Industry	Structural Steel, Rebar	Regular	Federated Steel Industry Mini Mill	Mini Mill	140,000	
Nigeria	Owerri	5.48781	7.020692	A	Metcombe Steel Co.	Rebar	Regular	Metcombe Steel Co. Rolling Mill	Rolling Mill	10,000	

* S = exact site location; A = approximate site location; C = cluster of sites.

Table A12. Construction materials database – wood (ERDC-CERL).

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Name	Site Type	Number of Employees Estimate	Notes
Nigeria	Akure	7.2577	5.204641	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Structural	Regular	Olukayode Sawmill (Nig) Limited	Mill		
Nigeria	Akure	7.2577	5.204641	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Plywood	Regular	Soarse Wood & Timber	Mill		
Nigeria	Akure	7.2577	5.204641	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Plywood	Regular	Premier Timber Industries (Nig) Ltd	Mill		
Nigeria	Akure	7.2577	5.204641	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Structural	Regular	Omoniyi Sawmill	Mill		
Nigeria	Akure	7.2577	5.204641	A	Piedmont Plywood	Structural	Regular	Akure Mill	Mill		
Nigeria	Apapa	6.438677	3.37693	S	Cotoaz Shipping & Logistics Limited	Plywood	Regular	Cotoaz Shipping & Logistics Limited Office	Office	21-50	13/15 Sapele Road, Wharf Bus-Stop, 101010 Apapa, Nigeria
Nigeria	Benin City	6.332543	5.598509	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Plywood	Regular	Iyayi Group of Companies	Mill		
Nigeria	Benin City	6.33459	5.617048	S	Jasper Wood Industry	Structural	Regular	Jasper Wood Industry Office	Office	18	
Nigeria	Burutu	5.35088	5.506339	A	Akewa Global Services Ltd	Structural	Regular	Akewa Global Services Ltd Mill	Mill	201-500	12 Akewa Complex Delta State, Ig1234 Burutu, Nigeria
Nigeria	Calabar	4.974273	8.342442	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Plywood	Regular	Seromwood Industries Limited	Office		
Nigeria	Calabar	4.974273	8.342442	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Plywood	Regular	Calabar Veneer and Plywood	Office		
Nigeria	Calabar	4.974273	8.342442	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Plywood	Regular	Calvenwood Veneer and Plywood	Mill		

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Name	Site Type	Number of Employees Estimate	Notes
Nigeria	Calabar	4.974273	8.342442	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Plywood	Regular	Wood Complex Ltd	Mill		
Nigeria	Delta	5.514652	5.964199	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Plywood	Regular	African Timber and Plywood	Mill		
Nigeria	Delta	5.874992	5.690873	S	Delta Forestry	Plywood	Regular	Delta Forestry Office	Office	103	
Nigeria	Edo	6.287749	5.611747	S	Cosource Ventures	Plywood	Regular	Cosource Ventures Office	Office	25	
Nigeria	Edo	6.332543	5.592329	S	Stanimose	Plywood	Regular	Stanimose Office	Office	5	
Nigeria	Enugu	6.457751	7.533104	S	Hilicin Limited	Structural	Regular	Hilicin Limited Mill	Mill	51-100	157 Chime, P. O. Box 1762, 400001 Enugu, Nigeria
Nigeria	Ibadan	7.379256	3.948113	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Structural	Regular	Amo Sawmills	Mill		
Nigeria	Ibadan	9.029854	7.482004	S	Famolin Enterprises	Structural	Regular	Famolin Enterprises Mill	Mill		P.O 9314, Ibadan, Nigeria
Nigeria	Ikeja	6.59802	3.353968	S	Rosohan System Nigeria Limited	Plywood	Regular	Rosohan System Nigeria Limited Office	Office		23, Amore Street, Ikeja, Lagos, Nigeria
Nigeria	Ikorodu	6.620119	3.519355	A	Yemi Productions Ltd	Plywood	Regular	Yemi Productions Ltd Office	Office	40	
Nigeria	Ilupeju	6.556371	3.356944	S	Aframero Limited	Plywood	Regular	Aframero Limited Office	Office	21-50	56 Town Planning Way, n/a Ilupeju, Lagos, Nigeria
Nigeria	Jos	9.910135	8.880124	S	Awa Holdings Limited	Plywood	Regular	Awa Holdings Limited Mill	Mill	21-50	Suite 11 Hillstation c.c Jos, nil Jos, Nigeria
Nigeria	Lagos	6.553942	3.336513	S	Bayrem Group International	Plywood	Regular	Bayrem Group International Office	Office		

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Name	Site Type	Number of Employees Estimate	Notes
Nigeria	Lagos	6.541562	3.366961	S	Bellet Construction Plc	Plywood	Regular	Bellet Construction Plc Office	Office	44	
Nigeria	Lagos	6.455854	3.396756	S	Bissy King International. Ltd	Plywood	Regular	Bissy King International. Ltd Office	Office	25	
Nigeria	Lagos	6.568051	3.383875	S	Hephizbah Resc and Inv Ltd	Plywood	Regular	Hephizbah Resc and Inv Ltd Office	Office	10	
Nigeria	Lagos	6.444054	3.320488	S	Malagas Ventures Nig	Plywood	Regular	Malagas Ventures Nig Office	Office	80	
Nigeria	Lagos	6.452557	3.390293	S	Obijiwealth Nig Ltd	Plywood	Regular	Obijiwealth Nig Ltd Office	Office	15	
Nigeria	Lagos	6.599422	3.373682	S	Orlean Farms Ltd	Plywood	Regular	Orlean Farms Ltd Office	Office	105	
Nigeria	Lagos	6.570755	3.372327	S	Tradecorp Investments Nigeria Ltd	Plywood	Regular	Tradecorp Investments Nigeria Ltd Office	Office	50	
Nigeria	Lagos	6.620146	3.301529	S	Ulman Investment Nig Ltd	Plywood	Regular	Ulman Investment Nig Ltd Office	Office	36	
Nigeria	Lagos	6.496259	3.337114	S	Woodvantage Ltd	Plywood	Regular	Woodvantage Ltd Office	Office	25	
Nigeria	Lagos	6.520251	3.370035	A	EG Woods Ltd	Plywood	Regular	EG Woods Ltd Office	Office	5	
Nigeria	Lagos	6.520251	3.370035	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Plywood	Regular	Epe Plywood Company Limited	Office		
Nigeria	Lagos	6.520251	3.370035	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Structural	Regular	Woodland Timbers	Mill		
Nigeria	Lagos	6.578961	3.366937	S	Epe Plywood Industries Limited	Plywood	Regular	Epe Plywood Industries Limited Office	Office		
Nigeria	Lagos	6.5361	3.340668	S	OBM Merchandise Ltd.	Plywood	Regular	OBM Merchandise Ltd. Office	Office	21-50	54 Bello Street, Papa Ajao, Lagos, Nigeria

Country	City	Latitude	Longitude	Precision*	Company	Product	Industry Type	Site Name	Site Type	Number of Employees Estimate	Notes
Nigeria	Odo-Ona	7.387122	3.837835	S	Forthnur Company Ltd	Plywood	Regular	Forthnur Company Ltd Office	Office	11-20	Flat3, FPC Building, Opp., Apata Our Lady Of Apostle, Odo-Ona, Ibadan, Nigeria
Nigeria	Ogbese	7.250074	5.195138	S	Thameswood Products	Structural	Regular	Thameswood Products Mill	Mill		Sawmill Akure-Owo Road, AKR2 Ogbese, Nigeria
Nigeria	Ogun	6.811747	3.922545	S	Shamen Global Concepts Ventures	Plywood	Regular	Shamen Global Concepts Ventures Office	Office	10	
Nigeria	Ologbo	6.052737	5.664185	S	Piedmont Plywood	Structural	Regular	Ologbo Mill	Mill		
Nigeria	Ondo	7.16741	4.810712	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Structural	Regular	Nigeria-Romanian Wood Industry	Office		
Nigeria	Ondo	7.16741	4.810712	A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Structural	Regular	NIROWI	Mill		
Nigeria	Port Harcourt	4.838312	6.995101	S	Shnahan Trading Investment	Plywood	Regular	Shnahan Trading Investment Office	Office	8	
Nigeria	Port Harcourt	4.813556	7.054485	A	Eddy Bros Nigeria Ltd	Plywood	Regular	Eddy Bros Nigeria Ltd Office	Office	50	
Nigeria	Sapele	5.894138	5.69345	S	African Timber and Plywood	Structural	Regular	Sapele Mill	Mill		
Nigeria	Victoria Island	6.431311	3.427141	S	Haran Resources Ltd	Plywood	Regular	Haran Resources Ltd Office	Office	51-100	Plot 1439 Sanusi Fafunwa Street, 11111 Victoria Island, Lagos, Nigeria
Nigeria				A	Nigerian-Romanian Wood Industries Limited (NIROWI)	Plywood	Regular	Eastern Match Industries	Mill		

* S = exact site location; A = approximate site location; C = cluster of sites.

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14. ABSTRACT To sustain itself as the world's premier land power, the U.S. Army needs the capability to support expeditionary forces by projecting a minimal basing footprint with reduced logistical burdens. Strategically sited Contingency Bases (CBs) allow the Army's expeditionary forces to rapidly respond and attack the enemy throughout the joint area of operations (JOA). Strategic conditions will be analyzed through the lens of eight OE variables—political, military, economic, social, information, infrastructure, physical environment, and time (PMESII-PT). The Army has neither a well-grounded methodology nor the tools to enable this type of strategic decision-making capability. Decision makers require reliable information about the situational dynamics of the operational environment to anticipate the impacts that siting and operating CBs will have on the local context, and to consider the effects of the site on the operation of CBs. The capability to anticipate CB impacts and resources draws upon the local population, which will become particularly important for engagement operations when CBs will have a longer duration of use and interaction with the local populace. This report considers access of building materials required for the construction of CBs and develops a methodology to acquire reliable information that can be replicated in other locations through the world. This work then validates the developed methodology with a case study of Maiduguri, Nigeria.					
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